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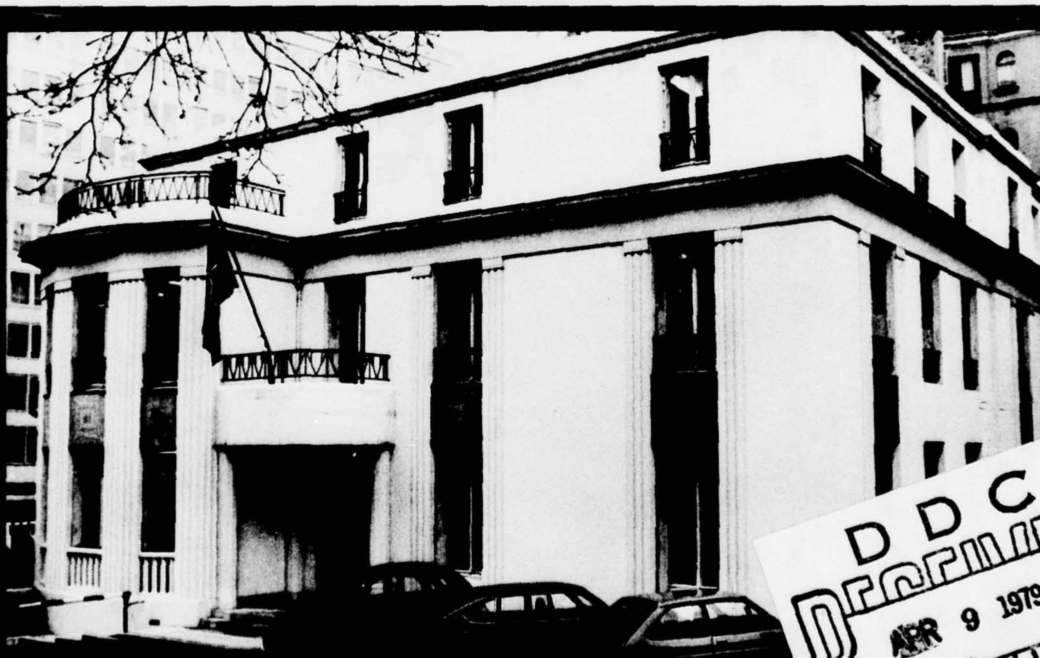

NORTH ATLANTIC TREATY ORGANIZATION

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(6) # AGARD HIGHLIGHTS. 79/1
MARCH 1979

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THE MISSION OF AGARD

The mission of AGARD is to bring together the leading personalities of the NATO nations in the fields of science and technology relating to aerospace for the following purposes:

- Exchanging of scientific and technical information;
- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;
- Improving the co-operation among member nations in aerospace research and development;
- Providing scientific and technical advice and assistance to the North Atlantic Military Committee in the field of aerospace research and development;
- Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field;
- Providing assistance to member nations for the purpose of increasing their scientific and technical potential;
- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community.

The highest authority within AGARD is the National Delegates Board consisting of officially appointed senior representatives from each member nation. The mission of AGARD is carried out through the Panels which are composed of experts appointed by the National Delegates, the Consultant and Exchange Programme and the Aerospace Applications Studies Programme. The results of AGARD work are reported to the member nations and the NATO Authorities through the AGARD series of publications of which this is one.

Participation in AGARD activities is by invitation only and is normally limited to citizens of the NATO nations.

The cover photograph shows the AGARD Headquarters building in Paris (Photo: Courtesy US Embassy, Paris)

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Foreword and Farewell

The very fine and inspiring address by General Miranda, Vice Chief of Staff, Portuguese Air Force, and the pictorial mementos included in this issue, will remind those of us who participated in our Annual Meeting in Lisbon last September, of not only the gracious hospitality of Portugal, but also its conscious and active effort to increase its involvement in AGARD.

Our host, General Bourbon, Portuguese National Delegate, organized a full and most interesting programme of activities on Portuguese National Day, which included the informative scientific presentations by AGARD Panel member, Dr Carvalhinhos, and Panel member-to-be, Dr Falcao, as well as technical visits of three impressive sites: the Air Force Maintenance Facilities at Alverca, a Nuclear Energy Centre, and LISNAVE, one of the largest and most modern ship repair facilities in the world, located just across the Tagus river from the capital city. Not the least of the activities in Lisbon was a series of meetings in small groups between some thirty Portuguese scientists and officers of six of our Panels. These meetings, organized thanks to the efforts of General Bourbon, proved quite successful and will no doubt help enhance the scientific benefits derived from Portugal's association with AGARD.

This issue also includes the written version of the excellent and comprehensive view of the future of propulsion and energetics presented by Dr Winterfeld, the Chairman of the Propulsion and Energetics Panel, at the Open Session of the National Delegates Board Meeting.

All in all, the Lisbon meeting was indeed a very successful one.

We now return to a sorrowful note on the personal side. We are deeply saddened at the passing away of two very active AGARDians, Professor Michael Anastassiades, National Delegate from Greece from 1960 to 1967, and founder member of the Electromagnetic Wave Propagation Panel, and Owen Matthews of the United Kingdom, member of our Flight Mechanics Panel. Our heartfelt sympathy goes to their loved ones.

This is the year of changeover of AGARD's Chairman/Director Team. You will find herein biographical sketches of the incoming Chairman, Dr Alan M.Lovelace of the United States, and incoming Director, Mr Jack Burnham of the United Kingdom.

In retrospect, AGARD's present Chairman, Mr Frank R.Thurston, and I both keenly sought and encouraged active participation of AGARDians at all levels. We felt that we needed to listen to the Nations and the Panels as well as to the needs of the Alliance as a body.

At National level there has been open discussion in our National Delegates Board Meetings toward insuring that the interests of the nations of the Alliance, large and small, are properly understood so that AGARD can be responsive to their needs.

Within the framework of NATO, AGARD has actively responded to the request of the North Atlantic Military Committee to undertake a study of potential technological advances in aerospace up to the turn of the century and their possible impact on military applications. This major exercise, better known as Project 2000, was initiated under the past Chairman, Dr Alexander H.Flax, and my predecessor, Mr Olav Blichner. It has called over the past three years for a tremendous effort and extensive resources by the nations of the Alliance which have cooperated and responded in a remarkable way. Project 2000 is nearing completion with final reports expected to be issued toward the end of this year.

While today's international environment makes us ever alert and responsive to the more immediate needs of the Alliance for defence planning purposes, we must not forget that the long-term future lies in maintaining a sharp scientific edge provided by our technical Panels which collectively form the very backbone of AGARD. A closer link between our

Panels has been successfully achieved in the past two years through semi-yearly meetings of Panel Chairmen organized and conducted entirely by themselves with the assistance of their Panel Officers. They thus have a forum through which they are able to present their collective views to our National Delegates Board and to AGARD management. Frank Thurston recalls that this is in fact a return to the original concept of Panel Chairmen Meetings of some twenty years ago.

In a parallel way, the creation of the Panel Executives Council, chaired in rotation by its members, has proved to be a most successful and effective venture within our Headquarters. Problems common among Panel Executives are aired and quickly resolved in addition to which many valuable suggestions made by the Council have been implemented and have resulted in greater efficiency of operation. One example of this is a set of AGARD operational guidelines, initiated by my predecessor, Olav Blichner, which were completed and put together by the staff in late 1976, and are being kept current as the needs for updating arises. They have proven to be invaluable to new as well as seasoned members of the AGARD staff.

Such participatory activities, encouraging and stimulating all levels of AGARDians to air individual and collective views, have already proven their value in terms of expressed needs, new ideas, and better ways to do things, all of which enable AGARD to carry out its mission within the Alliance even more effectively.

As my term of office approaches its end, I wish all AGARDians continued success in the future activities of this great organization, and express to them, and to my staff in particular, my sincere appreciation for the keen spirit of cooperation, dedication and friendship which I have experienced over the past three years.

Robert H. Korkegi

Robert H.Korkegi
Director, AGARD

Von Kármán Medals 1978

(Photo: Couresy Portuguese Air Force)

The presentation of Von Kármán awards for 1978 took place during the 14th AGARD Annual Meeting in Lisbon last September. Prof. Ir. Teunis van Oosterom (left) of The Netherlands, whose association with the Flight Mechanics Panel of AGARD goes back to 1960, was away in Africa at the time and so unable to receive the award personally. But a smiling Dr Alexander Flax, US National Delegate, (above) was obviously delighted to receive this token of recognition of his outstanding contribution to the work of AGARD from the hands of Chairman Frank Thurston of Canada. The silver medals are copies of the original gold medal presented to Dr Von Kármán: each recipient receives, in addition, a scroll bearing the citation related to the award, signed by the AGARD Chairman. The texts of the citations pertaining to Dr Flax and Professor van Oosterom were reproduced in our last issue (Highlights 78/2), on page 17.

1978 ANNUAL MEETING OF THE AGARD
NATIONAL DELEGATES BOARD

PORTUGUESE NATIONAL DAY

Members of the AGARD National Delegates Board attending the 1978 Annual Meeting in Lisbon in September were welcomed by the Vice Chief of Staff of the Portuguese Air Force, General J.M.B.Miranda. We reproduce here the text of General Miranda's address, delivered on the morning of Portuguese National Day (Tuesday, 19 September) in the impressive Fundação Calouste Gulbenkian building in Lisbon. In the afternoon, delegates were invited to visit local technical facilities – the famous LISNAVE shipyard, a Nuclear Energy Centre, and a Portuguese Air Force Maintenance Facility.

Welcoming address by

GENERAL J.M.B.MIRANDA, Vice Chief of Staff, Portuguese Air Force

Mr Chairman, National Delegates, Gentlemen,

It is both a privilege and a pleasure for me to welcome you to Portugal on the occasion of the 1978 AGARD Annual Meeting. I am acting on behalf of Air Force Chief of Staff, General Lemos Ferreira. He much regrets not having been able to join you here today due to the fact that he is out of the country. It is, therefore, in his name, and, in fact, on behalf of all the members of the Portuguese Air Force, that I bid you a most cordial welcome.

We feel very happy to be able to act as host to your 1978 Meeting and we hope that your work will be truly successful. We also hope that you will be able to escape from the hard work confronting you and be given an opportunity to feel the atmosphere of cordiality, friendliness and warm sympathy which flows out from the people of this country, so that you may look back on your stay with us as having been a pleasant visit as well as a time of fruitful labour.

Portugal, the oldest nation-state in Europe, is today in a difficult situation as a result of the deep political and economic changes following the end of a secular presence in Africa. Once it became confined to Europe, Portugal was naturally faced with the problem of deciding whether or not it should continue to belong to the North Atlantic Treaty Organization. As a matter of fact, Portugal has been far distant from the Alliance for over ten years, a period in which no type of military assistance was granted to the country. After some time of inevitable social unrest, but also a time for reflection, our internal political will asserted itself in favour of Portugal's remaining in essence a country of Western Europe, to which it is linked by strong cultural and economic ties that will become even closer when it joins the European Economic Community. As a result, the Portuguese people, through their representatives at the National Parliament, approved the continuation of Portuguese participation in the defence Alliance of Western European countries.

However, participation in the Alliance cannot be limited to a purely political attitude, although, in small countries such as Portugal, facing all kinds of dependencies and vulnerabilities, this assumes a vital importance in the balance with resources and military capabilities. To counter any possible external threat, the Portuguese Armed Forces should have, in concept, the capacity of dissuasion and reaction necessary to eliminate aggressive situations of low political costs, and be able to guarantee the time needed to simultaneously develop the adequate and opportune external political manoeuver and allow the Alliance to intervene.

But the Portuguese Armed Forces, which in Africa gained a vast professional experience, are now faced, when the treaty dispositions are enforced – particularly its Article 3 – with an obsolete weapons system totally unsuited to meet the challenges of the new situation.

On the other hand, the present context is more adverse to military expenditures, given the precarious economic situation and the strong anti-military feelings that usually follow a state of war.

The Portuguese economy, already formerly structurally sick, rapidly degraded not only as a result of the sudden rupture of the economic ties then existing with overseas territories, but also as a consequence of the repatriation and disbandment of troops, the flowing back of more than half a million Portuguese who had settled or were born there, the sharp rise in the price of petrol, etc.

The Portuguese Armed Forces are thus faced with an "impasse".

They have commitments to honour. They are experienced in active warfare. But they have not the material means indispensable to the fulfilment of the mission nor has the country the economic capacity to acquire them.

The military budget for 1978 is, to quote the Parliamentary Committee for Defence, one of "survival and maintenance" and not a "budget to take off and modernize". This unfavourable situation will undoubtedly continue for several years ahead.

Despite the black picture I have outlined to you, the Portuguese Air Force, with that aggressiveness which is a survival factor in air combat did not remain at rest waiting for better days.

It has been developing a great effort to modernize resource managerial methods both in the personnel and materiel fields in order to better use what it already

has and what it expects to get in the future. Theoretical concepts have been brought up to date. Training programmes have been renewed and a considerable number of officers and sergeants continue to be sent to friendly countries to attend courses of many different kinds.

This means that the Portuguese Air Force has sprung forward into a bold and optimistic programme leading to the acquisition of the skills necessary to efficiently explore new weapons systems.

On the other side, it has also set up a fairly wide range of plans and programmes related to the improvement of the existing fleet, after a technical-operational assessment of their validity in national and NATO terms. An example of this is the study for the up-dating of the radar system which is being carried out in close cooperation with the civilian counterpart, under the supervision of EUROCONTROL.

But all these efforts are not sufficient. The Portuguese Air Force has to approach its counterparts in the Alliance seeking aid as far as its plans for re-equipment are concerned, so that Portugal may become an active member of the Alliance and not merely a passive "aircraft carrier squadron" anchored in southwestern Europe where three major currents of sea traffic meet, unsinkable but vulnerable to hidden covetousness and threats.

It is also important to bear in mind that internal political stability (a basic condition for the confidence that is essential to an economic take-off) presupposes the existence of well-organised, balanced, and motivated Armed Forces, in which, taking into account the configuration of the operations threatre, the Air Force has necessarily a prominent role to play.

The Constitution of the Portuguese Republic attributes to the Armed Forces "the historic mission of guaranteeing the conditions that will allow the peaceful and pluralist transition of Portuguese Society to democracy and socialism".

We understand this mission in the sense of the Armed Forces not being an active or even "catalyzing" element intervening in the political process, but a stabilizing component ensuring the conditions for the regular functioning of the democratic institutions.

To sum up, we are convinced that the Alliance will be interested in making sure that one of its members, located in a position of acknowledged strategic value, is not so weak that it cannot, externally, contribute towards the collective defence of the Alliance, and, internally, guarantee the survival of democracy. For all these reasons, it is understandable that we in Portugal feel a special satisfaction in your presence and work. I believe it is true to say that the Portuguese people, because of their history and background, have always had an international outlook.

Each Portuguese, looking up the long length of his personal family tree, finds out that his branches extend over one or more of many different countries in the world. Many reasons can be found for this, but the point I would like to stress is the keen interest the Portuguese have always shown for the open spaces, for the long adventurous journeys, for descending into the mysteries of the unknown. Several centuries ago there happened in Portugal the phenomenon of convergence of the Mediterranean and North European (Norman) naval technologies. From its fusion with local techniques resulted the first resistant, manoeuvrable ships strong enough to endure long trips over the open, unknown seas.

The way towards European expansion via the Atlantic Ocean was thus open. Portugal was, by that time, a centre for research and development of nautical sciences, particularly naval technology, cartography, and cosmography.

In the present century, aerial navigation methods and instruments were developed in Portugal, enabling our crews to cover pre-planned long-distance air routes over the Atlantic with a precision not possible before. I recall the day and night crossings of the Southern Atlantic (the Portugal-Brazil route) in 1922 and 1927, respectively. The methods and instruments used were then adopted throughout the world. The Portuguese contributions to the development of science and technology related to aerospace is now reduced to an insignificant value.

As far as I know, research activity in my country is actually needing to be re-organized. Broadly speaking, it lacks functional planning and coordination, thus leading to a low output. Also, the investigator career is poorly legally defined and financially supported so that the national potentialities are not attracted to it. It is nonetheless true that the matter is at present being officially discussed and has also been taken up in the mass media.

If this situation is an inevitable consequence of the historical phenomenon of the slow evolution, over the centuries, of the cultural and political hegemony of the temperate subtropical and meridianal zones towards the cold, humid zones of the north; if it is an effect of the exhaust of energies spread over several continents as a result of the excessive duration of the colonial cycle; if it is an effect of the Mediterranean climate, tempered by the Atlantic, so calm and pleasant, more likely to invite to leisure, intellectual speculation and verbal demagogy, and less to tenacious, objective work; if . . .

These and many others are doubts, polemical and also in a certain way demagogic, to which I could not answer, nor is it of any interest to reply to at the moment. The point is that this North-South gap will tend to enlarge unless a closer relationship between the members of the Alliance can be established. This is another strong reason for us to regard your visit with the greatest interest.

I see this Organization then as being a source of stimuli which, I believe, will be able to give incentive, to guide and to support our own human resources to develop the most suitable programmes of research and development, despite the limited means we have at our disposal. After all, means are always limited, no matter how large they are.

In welcoming to Lisbon the distinguished representatives of NATO Member Nations, on behalf of the Air Force Chief of Staff, I can do no better than to wish that this Annual AGARD Meeting might be able to fulfil its objectives and I do hope that when you return to your countries you will take with you the pleasantest memories of your brief stay among us.

PORTUGUESE

TRANSATLANTIC TRIO. Dr John Martin (centre), US National Delegate, and his wife in conversation with compatriot John Walsh, NATO Assistant Secretary General for Defence Support.

LABOURERS FROM THE P.2000 VINEYARD Jurgen Wild (FRG) and Colonel Gilbert Bron (French Air Force), members of AGARD's Military Committee Studies Division currently engaged on the Project 2000 task, in conversation with Britisher John Scott-Wilson, Chairman of the P.2000 Review Board

FROM THE NORTHERN CLIMES OF NATO. From left to right, the Netherlands National Delegate, Mr van der Bliek, and his wife, Mrs Jager (wife of the Dutch National Coordinator), Mrs and Mr H.K.Johansen (Norwegian National Delegate), and Netherlander Mr P.Kant, Chairman of the AGARD Guidance and Control Panel.

PANORAMA

On the occasion of the 45th AGARD National Delegates Board Meeting, held in Portugal in September 1978, the Portuguese National Authorities gave a splendid Reception/Cocktail Party for their guests. This took place at the Monsanto Air Force Base, just outside Lisbon, which, from its hilltop site, enjoys magnificent panoramic views over the surrounding countryside.

We reproduce here some photos of the occasion, kindly provided to us by the Photographic Service of the Portuguese Air Force.

FRIENDS FROM THE FRG. National Delegate Trienes (right) in company with PEP Chairman, Gert Winterfeld, whose interesting presentation to the NDB is reproduced elsewhere in this issue of Highlights

ANGLO-US CONSORTIUM
British National Delegate, John Alvey, of the UK Ministry of Defence, sharing a pleasant moment with his wife (left) and Mrs Carol Martin of the US

THE BELGIANS FOREGATHER
The NATO Financial Controller, Mr J.Ceulemans, (left) and his charming wife in conversation with Major General Victor George and Major General Evrard, both of whom are National Delegates to AGARD

The new AGARD Chairman

Dr Alan M.Lovelace

In the course of its meeting in Lisbon during September last year the AGARD National Delegates Board approved with acclamation the proposal to appoint Dr Alan M. Lovelace to the Chairmanship of AGARD for the period of two years. The appointment takes effect at the conclusion of the Spring 1979 NDB Meeting, when the outgoing Chairman, Mr Frank Thurston, will be handing over the reins of office.

Alan M.Lovelace was born in St Petersburg, Florida, on September 4, 1929. Shortly after the end of the Korean Conflict, he served in the US Air Force from 1954 to 1956.

Dr Lovelace attended the University of Florida, Gainesville, Florida, receiving a Bachelor of Science Degree in Chemistry in 1951, a Master of Science Degree in Organic Chemistry in 1952, and a Doctor of Philosophy Degree in Organic Chemistry in 1954.

Following service in the Air Force, Dr Lovelace's entire professional career has been in Government service, for the most part at the Air Force Materials Laboratory (AFML), Wright-Patterson Air Force Base, Dayton, Ohio. There he initially did work in the field of fluorine and polymer chemistry. These efforts, on fluorocarbon and inorganic polymers, extended the useful temperature range over which polymers can be used.

In January 1964, he became Chief Scientist of the Air Force Materials Laboratory. In this role, he worked to realize the potential of very high-strength, very light-weight fibres being consolidated in a new class of materials called composites.

In 1967, he was named Director of the Air Force Materials Laboratory, and in October 1972, was appointed Director of Science and Technology for the Air Force Systems Command at Headquarters, Andrews Air Force Base, Maryland. In this role he provided technical guidance and management policy to eleven Air Force Systems Command Laboratories, five Liaison Offices, and the Command's European Office of Aerospace Research.

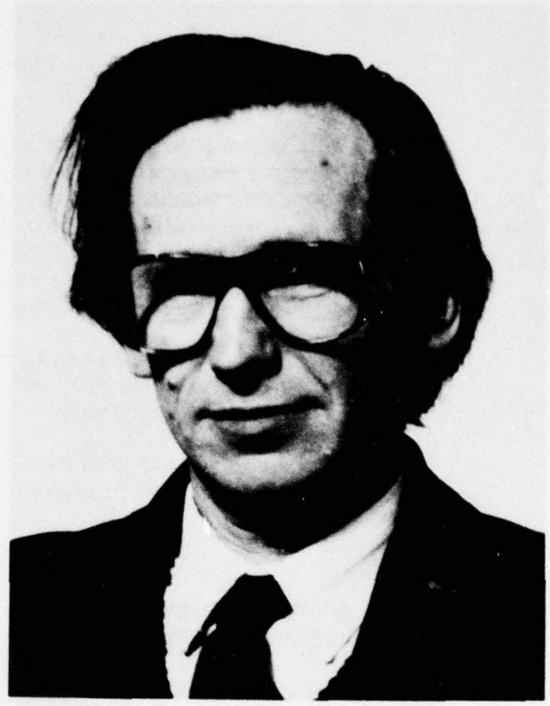
In September 1973, he bacame the Principal Deputy to the Assistant Secretary of the Air Force for Research and Development. In this role, he advised and assisted the Assistant Secretary in his direction of the entire Air Force Research and Development Programme.

In September 1974, Dr Lovelace left the Department of Defense to become the Associate Administrator of the NASA Office of Aeronautics and Space Technology. As the Associate Administrator for Aeronautics and Space Technology, he was responsible for the management of the research programme that will provide the basic science and technology advances that will be required for future military and civil aircraft, and the systems to exploit and explore space.

In June 1976, Dr Lovelace was appointed Deputy Administrator of NASA by President Ford.

.... and Director

On 1 July 1979, when the present Director of AGARD, Dr Robert Korkegi, relinquishes his appointment and returns to the US, it has been recommended by the National Delegates Board that the post be filled by Mr Jack Burnham of the UK. The appointment would be for a period of three years.



Mr Jack Burnham

Born and educated in Yorkshire before attending Bristol University, Jack Burnham graduated in 1954, receiving a Bachelor of Science degree with Special Honours in mathematics. He then joined the Royal Aircraft Establishment, initially at Farnborough, moving to Bedford at the end of 1955 with the Aerodynamic Flight Test Division. Remaining with RAE until late 1969, he specialised in work on aircraft dynamic response and, in particular, on aircraft behaviour during flight through atmospheric turbulence, and was responsible for the conduct of collaborative trials with the US and Canada involving flight measurements of turbulence in and around severe thunderstorms and in mountain wave conditions.

Jack Burnham took up a post with the Ministry of Defence in London in 1970 with responsibility for performance aspects of a number of aircraft then under development, including Jaguar and Hawk. In 1971 he became an Assistant Director in the Department of Industry with responsibility for the policy and finance of civil research on airframes and avionics returning to the Ministry of Defence in 1975 as Director of Aircraft Research. He took up his present post as Director of Resources and Programmes, covering the aeronautical sector of the UK Ministry of Defence research programme, in the spring of 1978.

Prospects for Propulsion and Energetics

by

G.Winterfeld

This brief historical review outlines the step-by-step enlargement in the scope of the Propulsion and Energetics Panel's activities over the years: the description of PEP's fields of activity indicates clearly its resulting interdisciplinary involvement and its interfaces with other AGARD Panels, e.g., FMP, FDP and SMP. Based on an outline of the present status of the propulsion technology, the main part of the presentation concentrates on the major development trends and problems expected within the aero gas-turbine propulsion field during the next two decades.

Future trends in ramjet and rocket propulsion as well as in the field of energetics, which is of concern to the PEP, are outlined, and a forecast given of future PEP interests and its scope of activities.

In conclusion, the role of PEP in the context of future technical development, its manner of approach, and its proper relation to the demands of the North Atlantic Alliance are stated.

1. HISTORY AND SCOPE OF WORK OF AGARD'S PROPULSION AND ENERGETICS PANEL

Twenty-six years ago, in 1952, the Propulsion and Energetics Panel was founded as one of the original technical groups of AGARD. It started its life as the Combustion Panel, thus signalling that the main scientific emphasis at that time was on a very important but limited part of the energy conversion progress in aerospace propulsion systems, namely on combustion, by which chemically-bonded energy of a fuel is released and converted into thermal energy. Several outstanding publications testify to those early days' activities. Even before the end of the Fifties, however, the scope of the Panel had broadened to include the conversion of thermal energy into kinetic energy; consequently its name was changed to Combustion and Propulsion Panel. High Mach number propulsion by ramjets and their derivatives, using subsonic and supersonic combustion, was the focus of activity at that time. Another field of interest was added with the advent of the space age, namely, energy conversion for space applications, ranging from chemical rockets, to magnetohydrodynamics, on-board power generation for satellites and electric propulsion systems for space vehicles. It was in 1965 that the panel adopted its present name: Propulsion and Energetics Panel.

Another shift of emphasis occurred in the second half of the Sixties. Whereas up to that time the Panel had been concerned to broaden and improve the fundamental knowledge needed as the basis for advanced systems it became necessary to take into account also the near-term needs of propulsion systems. So it was quite natural that the Panel was confronted with aero gas-turbine propulsion systems, their design, development and operation. A milestone marking the beginning of this development was the 1966 spring meeting on Gas Turbines, at a time when the high by-pass ratio turbofans were in their formative stage. Since then, the Panel has devoted most of its efforts to the needs of aircraft and missile propulsion, in accordance with the AGARD charter and the requests of the National Delegates.

Dr Winterfeld joined the Institut für Thermodynamik und Verbrennung of the Deutsche Versuchsanstalt für Luftfahrt in 1957 having finished his Mechanical Engineering studies at the Technische Hochschule Aachen. There, he was on the research staff for the investigation of blade cooling. As a research engineer, he concentrated on combustion problems, combustor modelling, flame stabilization and mass exchange. In 1967, Dr Winterfeld was appointed Head of the Combustion and Flow Section in the Institut für Luftstrahlantriebe where his research activities covered the complete field of the aero gas-turbine and ramjet propulsion; in particular, combustor problems, exhaust pollution and supersonic combustion. In 1968 he received his degree of Doctor-Engineer and since 1974 has been an appointed lecturer at the Technische Hochschule Aachen. In 1973, Dr Winterfeld became Head of the Institut für Luftstrahlantriebe in the DFVLR and is now the Director of this Institute, which has been renamed Institut für Antriebstechnik. Early this year, Dr Winterfeld was appointed Professor at the Technische Hochschule Aachen.

Dr Winterfeld joined the AGARD Propulsion and Energetics Panel in 1972. He was elected Deputy Chairman in 1975, and he has served as Chairman of the Panel since 1977.

The propulsion system of an aircraft or a missile is a major and complex subsystem, the development of which still needs more time than that of an airframe. It combines fundamental knowledge from several basic disciplines and converts this into technologies, on which the design and development of an engine and its integration into the aircraft system is based. This process (Fig.1) defines the specific activities of PEP as well as the interfaces with our neighbouring Panels. Our first two tasks are to produce and to improve basic knowledge and to convert this knowledge into the technology needed for engine design. Here we have interfaces principally with FDP and SMP. Our third field of activity, engine/airframe integration, is highly interdisciplinary, involving again close contacts with FDP and also with FMP. The operational aspects of engines are the fourth area, in which the Panel's task is to enhance the exchange of experiences between engine users and designers. Finally energetics, our fifth field of activity, concerns both the engine and the aircraft; it is covered much in parallel with the propulsion activities.

Figure 2 provides a short survey of key words characterizing these five activities. The fundamental knowledge to be considered ranges from fluid dynamics, thermodynamics, chemistry, material properties, structures and their mechanical behaviour, to manufacturing aspects and measuring techniques. The technological area combines analytical procedures with experimental or hardware developments, such as performance prediction and systems application studies, design philosophies, component technologies including subsystems, testing techniques and power plant control. Integration is first concerned with putting together inlet, gas, generator, fan and nozzle or propulsor (propeller or rotor) thus forming the propulsion system and second, with integrating this system into the airframe and the flight control system. The operational aspects cover the accomplishment of missions for which the engine is designed, all the reliability aspects including health monitoring, maintenance and overhaul as well as in-service-deterioration; furthermore the operational side includes safety aspects like vulnerability and fire safety, and last but not least, life-cycle costs and related problems. In the fifth area, the Panel reviews the energetics aspects covering fuels and lubricants, their specifications, qualities and availability, aircraft fuel systems, as well as on-board power generation for aircraft systems by means of auxiliary or emergency power units, batteries and other exotic devices.

It is quite clear that a technical survey on such a large field within a limited frame must naturally neglect several important aspects. It is therefore our main intention to discuss those fields of propulsion where major developments or problems will influence technical progress in the next two or three decades. The survey concentrates on military propulsion but takes into account also aspects of commercial engines since there are cross-correlations which have beneficial effects on both sides. Various members of the Propulsion and Energetics Panel as well as colleagues from other organisations have provided me with substantial statements and comments on future prospects of propulsion; in particular, I have to mention Dr A.Wennerström of APL, Dr J.Dunham of NGTE, Mr A.Jackson of Rolls Royce and Ingenieur en Chef M.Pianko of ONERA, Mr B.Crispin of MBB, Dr H.Grieb, Dr K.Bauernfeind and Dr D.Hennecke of MTU; their most valuable and helpful assistance in the preparation and the reviewing process is gratefully acknowledged

2. PRESENT STATUS OF ENGINE TECHNOLOGY

To-day's military engines are the product of four decades of breathtaking development towards outstanding performance and compactness which is exemplified impressively by the comparison (in Figure 3) between a J79-engine, widely used in many airforces of the alliance, and modern engines, like the RB 199 now entering service. The length of the modern engine is reduced to approximately 60 percent. Thrust-to-mass-ratios of military engines have increased from values about 3 to presently 7 to 8 (Fig.4), and, as the figure shows a similar progress has been achieved with commercial engines, which always have profitted from the technological development of military engines. While the simple, straight turbojet governed the scene in the fifties it is now the turbofan with bypass ratios up to 1 or more, which sets the stage, (Fig.5) thus bringing the specific fuel consumption down to values of about 0.8 kg/daN.h. at altitude cruise conditions. With the large turbofans for civil aircraft using bypass-ratios in the order of 4 to 6 altitude cruise specific fuel consumption is even lower, with figures around 0.6 kg/daN.h. Overall pressure ratios are now between 20 and 30, maximum turbine inlet temperatures have risen well above 1600 K for military engines; for civil engines these values are between 1500 and 1600 K. Thrust augmentation by afterburning increases the dry thrust levels by 80% or more. At the same time, these modern engines exhibit fairly good operating flexibility and mechanical configurations have grown in integrity to the point of operation without failure for many hundreds of stress and thermal cycles. The price for these impressive performance levels is a significant increase in complexity as well as the advent of new problem areas such as deterioration, clearance and sealing problems or degradation of high pressure turbine efficiencies. This in turn demands increasingly complex development analysis and test procedures, stringent qualification and certification criteria as well as complex and costly maintenance concepts. Thus life cycle costs are increasing, too.

3. FUTURE ENGINE DEVELOPMENTS TRENDS

3.1 Future Requirements

The development trend of future military engines depends mainly on

- the future mission requirements which have to be deduced from the expected military threat, and
- on the restraints set by the resources available for procurement and operation of airborne weapon systems.

The latter point is of great concern presently. The decreasing financial resources for procurement and operation of military equipment will continue to emphasise the need for design-to-cost and for decreased life cycle cost. This will influence engine design as well as engine usage in air forces, and also maintenance and overhaul procedures. Feed-back from the engine user to engine designers must be improved if continuing advances in level of engine capability are to be maintained. Technologies will be developed in the next three to five years which will bring improvements with respect to maintenance costs, spare engine consumption, engine deterioration and unit combat readiness. The improvements concern three areas: engine structure including

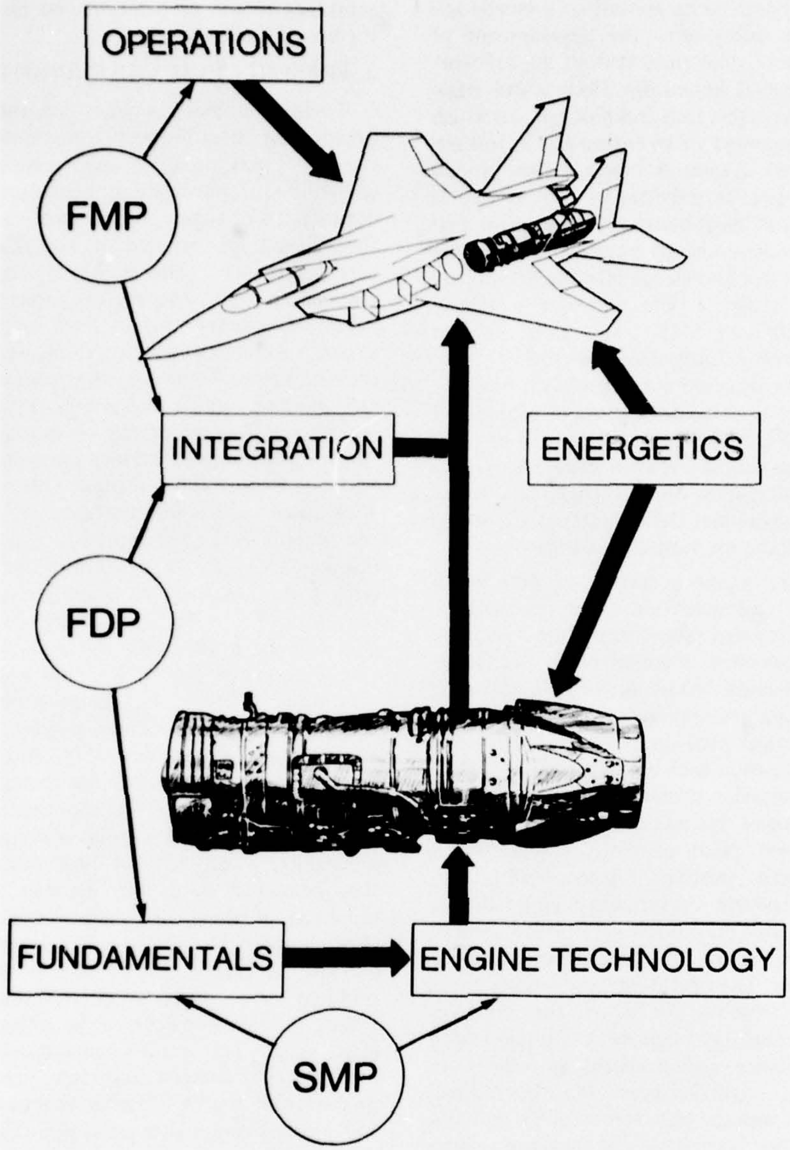


Fig.1 PEP's five fields of activities and interfaces with other Panels

FUNDAMENTALS	ENGINE TECHNOLOGY	INTEGRATION	OPERATION	ENERGETICS
FLUID DYNAMICS	PERFORMANCE PREDICTION	INLET/NOZZLE	MISSION ACCOMPLISHMENT	FUELS
THERMOCHEMISTRY	DESIGN PHILOSOPHY	AIRFRAME	POWER PLANT RELIABILITY	A/C FUEL SYSTEMS
HEAT TRANSFER	COMPONENT TECHNOLOGY	HIGH-LIFT-DEVICES	MAINTENANCE/OVERHAUL	LUBRICANTS
STRESSES/VIBRATIONS	CONTROL TECHNIQUES	FLIGHT CONTROL SYSTEM	DETERIORATION	ON-BOARD-POWER GENERATION
MATERIALS	TESTING TECHNIQUES		LIFE CYCLE COST	AUXILIARY/EMERGENCY
STRUCTURES	SUBSYSTEMS		FIRE SAFETY/VULNERABILITY	BATTERIES ETC.
MANUFACTURING				
MEASUR. TECHNIQUES				

Fig.2 Keywords of PEP-activities

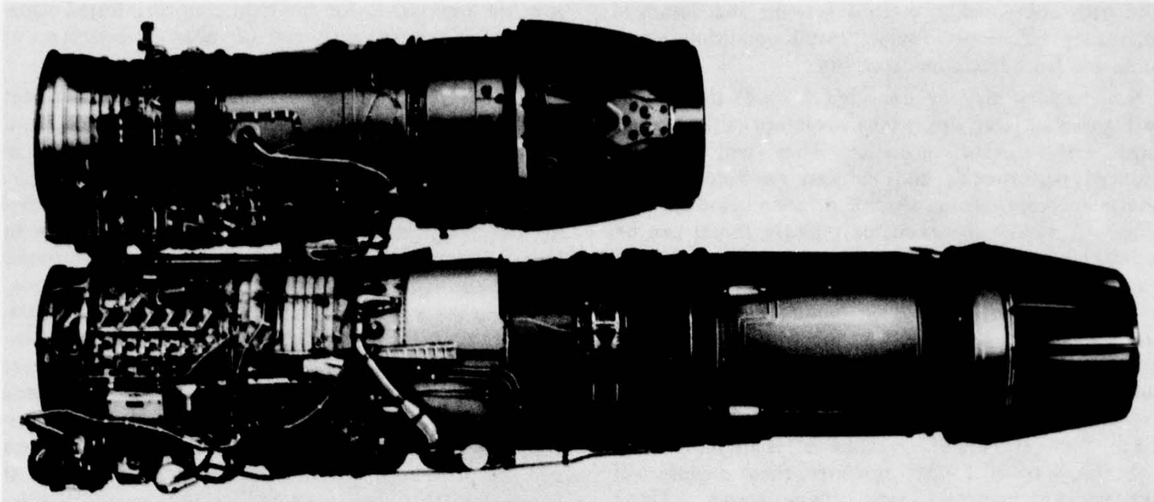


Fig.3 Progress of military aero engine design – above: RB 199-engine; below: J79-engine. (Courtesy MTU)

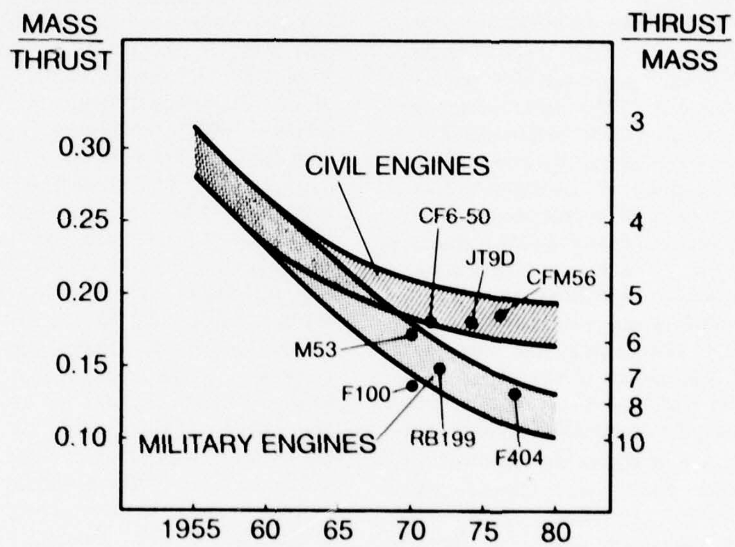


Fig.4 Progress of mass/thrust ratio of aero engines

THRUST/MASS		7 ... 8
PRESSURE RATIO		20 ... 30
TURBINE INLET TEMPERATURE		1500 ... > 1600
BYPASS-RATIO	MILITARY	0.3 ... 1
	CIVIL	... 4 ... 6
SPECIFIC FUEL CONSUMPTION (CRUISE)		0.6 ... 0.8 kg/daN · h
AB THRUST AUGMENTATION		... 80%

Fig.5 Technical data of modern aero engines

STRAIGHT TURBOJET OR VERY LOW BYPASS-RATIO TURBOFAN

PRESSURE RATIO $\pi \geq$ 20 ... 24

SINGLE SHAFT

TURBINE INLET TEMP. $\geq$ 1800 K

MECHANICALLY SIMPLE DESIGN

ENHANCED RELIABILITY

Fig.6 Features of future fighter engines

flow path components, control systems and advanced diagnostics techniques for improved condition monitoring and fault detection capability.

New engines may be expected towards the end of the Eighties or later which take advantage of the lessons learnt with current engines. They will combine advanced performance and reduced mechanical complexity, according to the specific future mission requirements. Although the expected military threat can be predicted with limited probability only, it seems to be clear that, in the future as well as before, missions will be of prime importance which require highest specific thrust and high excess power for flight manoeuvres. Therefore one can expect one of the new engine concepts to be a dual-flow-path engine with very low-bypass-ratio, in the order of 0.2–0.3 or eventually, a straight turbojet, (Fig.6). Pressure ratios are most likely in the order of 20 to 24; however, these engines will have fewer compressor and turbine stages. Using furthermore a simplified afterburner, a simple design concept will result which contributes to decreased engine unti costs, reduced maintenace/overhaul costs as well as improved reliability. High turbine inlet temperatures up to 1800 K will result in high specific thrust levels, promising improved performance and reduced dimensions, thereby reducing installation losses.

In the future development of these types of engines, further aircraft performance improvements could be achieved, if variable geometry in the turbomachines and a variable exhaust nozzle are used to better match inlet and engine airflow thus reducing spillage losses and base drag. Eventually, the requirements for the next generation of engines would also be supplemented by the demand for providing aircraft control during high-angle-of-attack flight, e.g. by thrust-vectoring. There is also a certain prospect that for air-superiority as well as for interceptor/intruder missions supersonic flight capabilities at medium and high altitudes may gain importance. This would influence the choice of the engine design points so as to reduce the importance of afterburner operation, for example, to acceleration periods only.

A second future trend of engine development may emanate from economic and tactical reasons, which demand engines having increased multi-mission capability and greater operational flexibility. Suitable candidates for this engine class are bypass engines, the thermodynamic cycle of which can be adjusted according to demand, e.g., for high specific thrust or low specific fuel consumption. Variable geometry in compressors, turbines and exhaust nozzles as well as for the bypass flow splitter is needed in order to obtain the required degree of controllability of airflow between core engine and bypass duct (Fig.7). Digital control systems, now in development are well suited to handle the resulting multiple control variables. Regarding the expected weight increase and the increased complexity one can say that the justification of these engines strongly depends on the future progress in component technology as well as on the overall gains which they promise for the mission accomplishment. Presently engine designers are rather pessimistic about the future of this engine category.

A very stringent requirement for future military propulsion systems will be the reduction of detectability by infrared sensors or radar, etc. It is necessary to re-examine the design philosophy of military engines and their integration into the aircraft in order to identify suitable approaches for the reduction of infrared signatures of engine exhausts and of radar cross-sections of engine inlets.

No survey of future developments of aero gas-turbines would be complete without a glance towards civil engines, because these will have influence also on certain military missions, e.g., on those with long endurance. The design of future civil engines will be characterized by the need for fuel conservation and reduction in Direct Operating Costs (D.O.C.). Of prime importance will be the reduction of the specific fuel consumption, as well as the weight and dimensions of engines. Studies, like NASA's Energy Efficient Engine Program, show that the use of both advanced cycles and component technology promise considerable improvements. Engine development engineers are now learning how to overcome the problems associated with high temperatures and pressures in present-day large engines. Therefore, it is expected that engines to be built in the early Nineties will show cycle pressure ratios of 38 or more, turbine entry temperatures up to 1800 K and by-pass ratios of 6 or more (Fig.8). Benefits both for fuel economy and for noise reduction will be achieved by mixing the by-pass and core flow before they leave the nozzle. As illustrated in Figure 9, reductions in fuel consumption of 12% or more compared to existing high by-pass turbofans and in D.O.C. of at least 5% are expected. Regarding the increase in fuel price, which is almost sure, these improvements are comparable to those achieved with the introduction of the high by-pass ratio turbofan ten years ago. One should have in mind, however, that this progress pertains to large engines, above 100–120 N thrust, only. For smaller engines, these progressive thermodynamic cycles are less favourable because, due to decreasing physical size of the engines, higher losses will very soon balance the expected cycle and efficiency gains.

Another trend towards advanced energy-efficient propulsion systems concerns the so-called prop-fan concept, which features advanced propellers for high flight Mach numbers, using six to eight highly-loaded blades with supercritical profiles and backward sweep in the outer parts of the blade for minimizing compressibility effects. Employing composite structures for the blades, and advanced gas generators as prime movers using thermodynamic cycles as mentioned above a further reduction in fuel consumption of 10–15% is estimated in comparison with advanced turbofans. Such a return to the old days of the turboprop, however, would be accepted by the air passenger only if the comfort of the ride does not deteriorate. On the other hand, for military long-endurance missions, the prop-fan may show significant benefits, for example by increasing the radius of action by 50–60%.

The energy situation has also revived the interest in regenerative-cycle engines using heat exchangers. This concept promises fuel savings of another 10% approximately, and needs fewer turbomachinery stages, since the optimum cycle pressure ratio is lower. Thus at least part of the complexity and weight added by the heat exchanger can be compensated. The realization of this concept, however, depends entirely on the successful development of compact and light-weight heat exchangers with high effectiveness and good reliability. This type of engine cycle may possibly characterize the future development trend of shaft power engines, e.g. for helicopters, which for military applications would

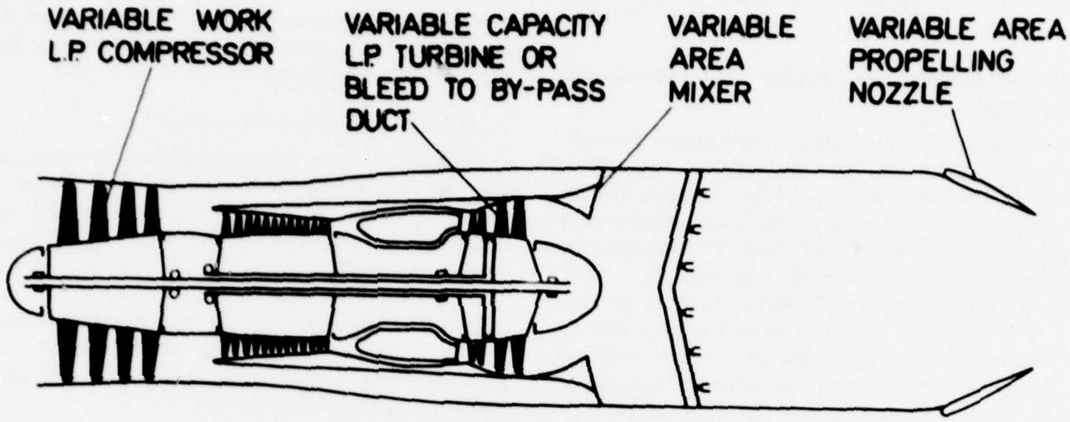


Fig.7 Scheme of a variable-cycle-engine (VCE) (AGARD-CP-205)

PRESSURE RATIO	38 ... 45
TURBINE INLET TEMP.	1700 ... 1800 K
BYPASS RATIO	≃ 6
THERMAL EFFICIENCY	≃ 56%
PROPULSIVE EFFICIENCY	≃ 63%
MIXED FLOW TURBOFAN	

Fig.8 Details of future large civil turbofans

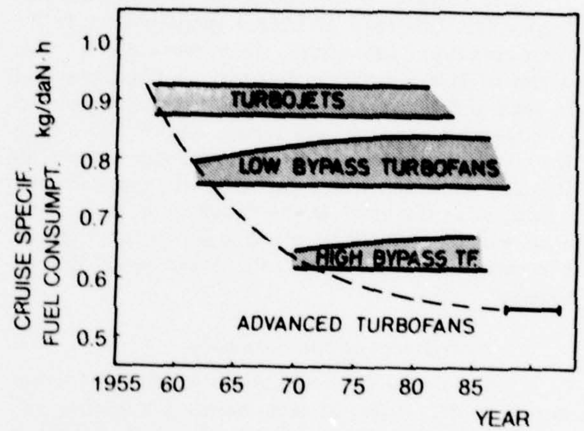


Fig.9 Development of cruise specific fuel consumption of aero gas turbines with time[5]

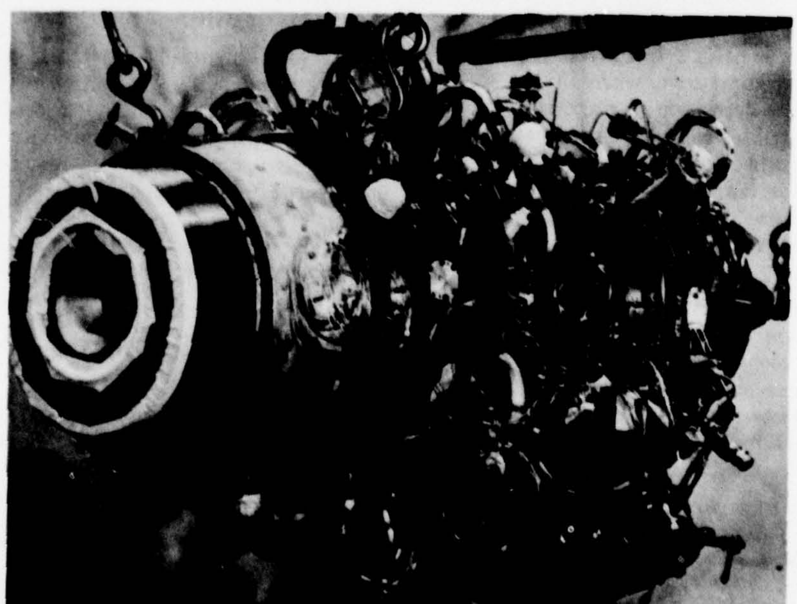


Fig.10 Advanced Turbine Engine Gas Generator (ATEGG). (Courtesy Aero Prop. Lab., USAF)

also promise a considerable reduction in infrared signatures.

3.2 Future Progress in Engine and Component Technology

The envisaged improvements in aero engine development depend essentially on the progress realized in component and subsystem technology. To achieve these goals, engine and component research and development programs presently under way must be continued or established according to specific requirements. Since for military engines the future specifications are not yet known precisely, the technical expertise provided by these technology programs must be broad enough to cover the whole range of requirements likely to become real. The programs must include the demonstration of advanced component technology as well as the evaluation of advanced engine concepts by means of demonstrator gas-generators.

Figure 10 shows as an example the Advanced Turbine Engine Gas Generator (ATEGG) sponsored by USAF Aero Propulsion Laboratory, which illustrates the high degree of instrumentation necessary for data collection in such R & D programmes. This field of engine and component technology will remain one of PEP's main working areas, where the Panel will enhance progress by stimulating discussion and exchange of experience and results, as in the past. In the following Sections, some areas will be highlighted where major progress can be expected and where the PEP's future work will be focussed.

3.2.1 Aerodynamics of Turbomachines

Major goals for the development of advanced turbomachines are, firstly, to seek increased efficiency and stage loading, in order to decrease the number of stages for a given pressure ratio, and, secondly, to establish improved design methods in order to reduce the development risk, associated with the still widely-used cut-and-try methods. Apart from limited progress towards higher tip speeds, increased stage loading without compromising efficiency or working range will benefit from new blade profile designs, like the so-called supercritical blades for compressors, where losses can be reduced by shock-free deceleration on the blade suction side. Low-aspect-ratio blading in conjunction with advanced manufacturing techniques show promise of vibration control for fan blades, such that eventually it will be possible, hopefully, to dispense with mid-span dampers, which still cause considerable losses to-day.

For cooled high-pressure turbines it is essential that aerodynamic losses are diminished by careful control of cooling air admission and secondary flows. Improvements in design techniques can be expected from advanced numerical calculation techniques (for example, blade profiles can be designed according to demand from given optimized pressure distributions, as is the case for the above-mentioned supercritical airfoils).

New diagnostic tools like Laser-Doppler or Laser-Two-Focus velocimetry provide experimental insight into flow processes in rotors, hitherto completely inaccessible. Results of this type, as shown in Figure 11, provide an excellent basis for the development of physical models on which three-dimensional flow-calculation methods can be designed. These methods will greatly enhance the design of turbomachines, especially those with stronger 3-D-effects, like fans, centrifugal compressors and LP-turbines, and hence contribute to a more reliable engine design and to reduced development costs.

3.2.2 High-temperature Technology

Progress of aero gas-turbines towards higher thrust per unit of airflow and improved fuel economy are connected with higher gas temperatures and, hence, demand better high-temperature materials and improved cooling techniques. Although the prospects of conventional superalloys are limited, now, some modest increase in the working temperatures (approximately 30–40 deg.) or the lives of turbine blades can be expected from directional solidification or by growing them as single crystals (Fig.12).

Metal temperatures of approximately 80–100 deg. above present values are promised by eutectic materials, like COTac (Fig.13), where by a carefully-controlled solidification process, long intermetallic fibres of high strength are formed within a ductile matrix. Futher improvements in hot-part lifetimes can be expected by the use of oxidation and corrosion-preventing coatings. If applied with thicknesses in the order of 0.2–0.4 mm these protective layers offer considerable potential for lowering metal temperatures, because they also act as thermal barriers. These prospects are very important not only for turbines but also for combustor liners, particularly in view of alternative fuels.

In the far future, we may eventually use ceramic materials, like silicon nitride or carbide, which can be exposed to gas temperatures of 1650 K without protective cooling. In that field, research and development work aiming at vehicular gas turbines has achieved considerable progress; for example, rotors have been spun successfully for 25 hours or more at temperatures of approximately 1500 K. Once the engine designer has learned how to live with the unfavourable properties of ceramics and design rules for brittle materials have been developed, one can expect these materials to be applied also in aero engines, at least for static and lightly-loaded parts.

As long as metallic materials are used at elevated temperatures in the hot section of gas turbines, blade cooling has to be applied and needs improvement, if the ambitious goals discussed above are to be realized. The current film cooling technique has to be developed to higher effectiveness and to lower flow losses. In the future it will be supplemented by transpiration cooling techniques, and new approaches like precooling the turbine cooling air may help to bring about further progress.

3.2.3 Advanced Materials, Manufacturing and Design Techniques

Much progress towards lighter, more compact and more reliable aero engines can be expected from the adoption of advanced materials, manufacturing and design techniques. Due to their good strength/density characteristics, composites such as boron fibre aluminium or carbon fibre epoxy materials are very promising for further reduction in engine weight. The use of the latter material will however be restricted, in the near future, to static parts like casings or nacelle structures and much remains to be learnt before it could be used in rotating parts. Powder metallurgy of titanium

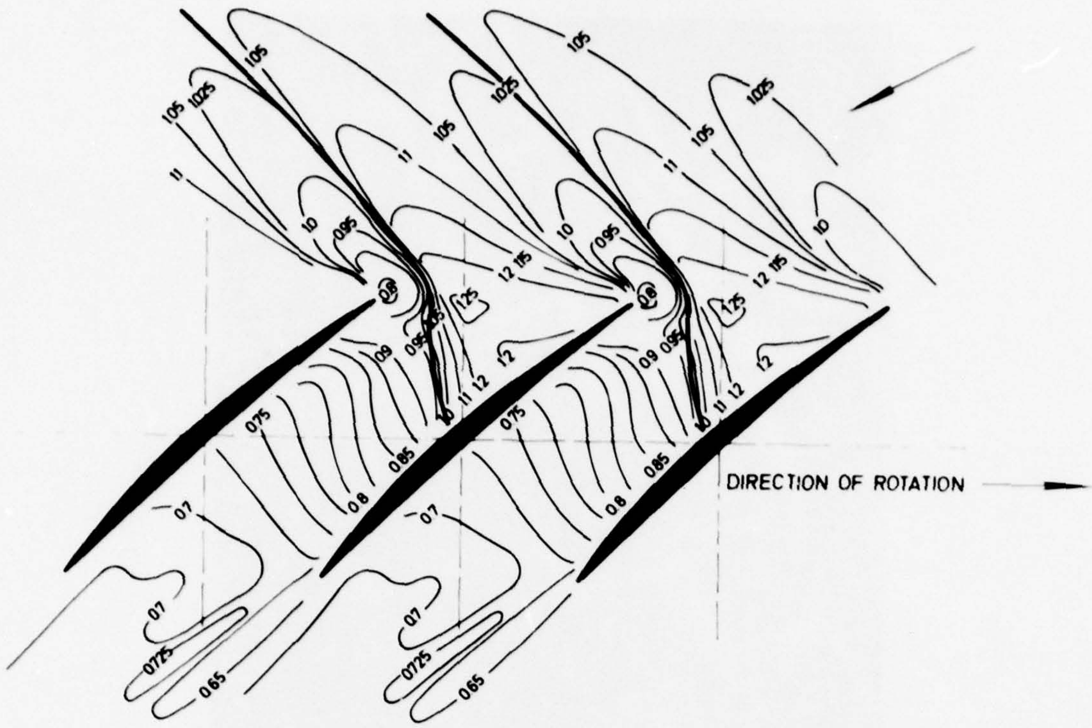


Fig.11 Flow field inside a transonic compressor stage, measured with the Laser-Two-Focus-Method.
(Lines of const. Mach number; 45% blade height; 20 000 r.p.m.) (Courtesy DFVLR)

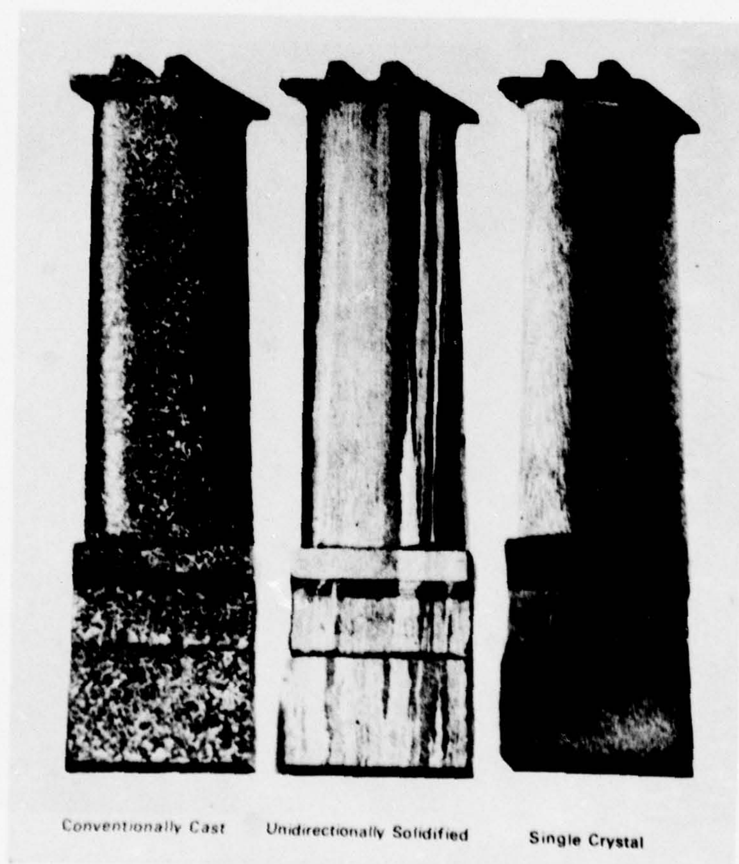


Fig.12 Experimental turbine blades, (Courtesy NGTE)

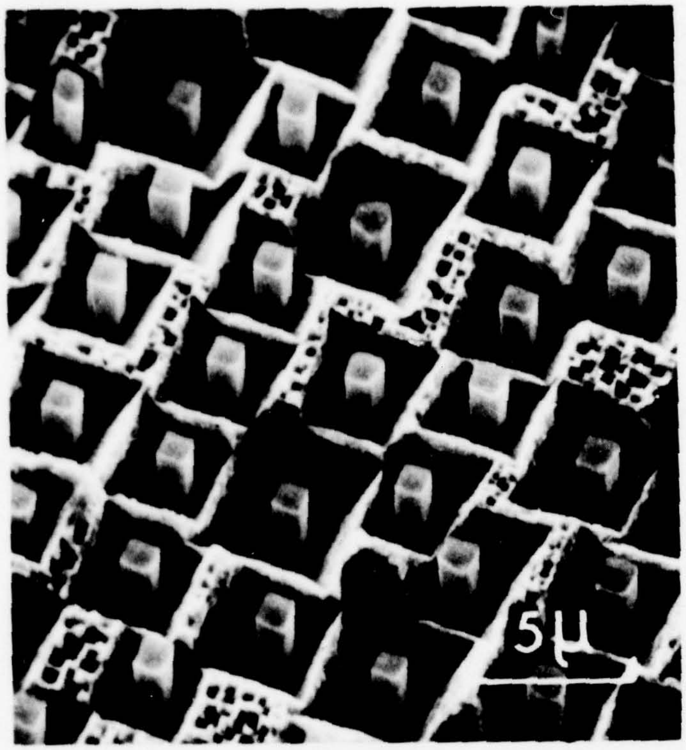


Fig.13 Micro photograph of the internal structure of a directionally solidified eutectic (CoTaC) (Courtesy ONERA)

Fig.14 X-ray photograph of the Rolls Royce Viper high pressure turbine, showing gas path seal (Courtesy Rolls Royce)

and high-temperature superalloys in connection with manufacturing techniques like hot isostatic pressing will allow compressor and turbine discs to be made to near-net shape which can withstand higher rotational speeds and at the same time promise better fatigue behaviour as well as better utilisation of these expensive materials. Though partially in use presently, advanced manufacturing techniques like diffusion bonding, laser beam welding, electron beam drilling or electrochemical machining will, in the future, allow production of more sophisticated structures, which will contribute to improved performance of the engine, and to reduced manufacturing costs.

Advances in design techniques are on the way which will allow a better thermal matching of static and rotating parts, during transients, for example by active clearance control with compensating casings or by using abradable sealing materials. They are based on improvements in non-destructive testing techniques like X-ray inspection of engines, which allow clearance observation during engine operation, as it is illustrated by Figure 14. Other techniques, such as performance monitoring procedures for registering fatigue life consumption, and improved in-situ inspection procedures will increase engine reliability and provide cost-savings in the maintenance and overhaul sector.

3.2.4 Combustors and Afterburners

Rising combustor exit temperatures, the envisaged use of alternative fuels with higher C/H-ratios, the requirement for soot-free combustion as well as for low exhaust pollutant emission for civil engine combustors define the frame of development problems to be encountered with advanced combustors. Besides causing difficulties with generating suitable exit temperature distributions, the rising gas temperatures influence mainly liner cooling. Here, improved and more effective cooling methods are needed together with better liner materials, e.g., oxide dispersion strenghened materials, in order to ensure adequate liner life. This problem will become even more serious with the use of the alternative fuels which show higher soot formation than with conventional fuels. A solution may be expected from the development of an adequate control of the combustion process (by using, for example, more homogeneous fuel-lean mixtures with prevaporisation or staged combustion, as required for low-pollutant combustors in civil engines). The development has to be guided such that burner systems with adequate multi-fuel capability can be built. This approach, however, will call for improved ignition devices, capable of reliably relighting combustors with low-volatility fuels in the whole flight envelope. Athough much experience has been accumulated up to now, combustor development still contains a great deal of experimental cut-and-try work, contributing to increased cost, because many testing hours have to be spent at high-pressure/high-temperature conditions. Improvements can be expected in this field from research work on analytical combustor models. This will enable computational trade-offs prior to testing so providing guidelines to the combustion engineer, who, by this means, will be able to design more rigorous testing programmes. Turning to afterburners, very similar problems have to be solved. Increased combustion efficiency and lower soot-formation levels at reduced afterburner length – for the sake of more compact engines – demand improvements in fuel-air mixture preparation without, however, enhancing combustion instabilities, in particular, when alternative fuels are used. Here again, liner cooling will need improvements.

3.2.5 Power Plant Control

Hydromechanical control systems of aero engines are being gradually replaced by electronic control devices, and many modern military engines are already equipped with analog systems. However, the future will belong to digital control systems, in particular when increased numbers of control modes are involved. Small and light-weight computers will be available very soon, which are programmable and thus can be standardized for use with several propulsion systems. They will be able to handle also the inlet control, thus closely matching inlet and engine airflow, and their integration into a flight control system of an aircraft is a question of time, depending largely on the development of flight control system strategies. However, the non-availability of suitable sensors poses serious problems for the use of digital controls systems, presently. Also, completely satisfactory safety strategies must be evolved.

3.3 Integration into Airframe

The most important area of integration concerns the engine inlet, because mismatching between engine and inlet can cause considerable additional drag as well as serious operational problems due to engine surge or blade vibrations. Therefore, although intakes normally fall into the responsibility of the aircraft designer, the engine designer is interested in a highly efficient integration of the engine, the inlet and the airframe. Progress can be expected from a better optimisation of inlets for subsonic and transonic speeds. Another benefit could come from combining the control of variable inlets with engine control, which will be made possible by advanced digital control systems. Furthermore, there are prospects that, once current research efforts on the statistical properties of dynamically distorted inlet flows are successfully completed, the need for elaborate inlet testing with expensive real-time high-response measuring techniques would be reduced considerably. Thus, there is hope for cost reductions in inlet design and testing. Improved manoeuverability during air-to-air combat at high subsonic speeds demands wide incidence ranges of operation for intakes; therefore more experimental research has to be done on high-incidence cowl lips, which may eventually need the use of variable geometry lips or boundary layer control. Similar requirements exist for the integration into the airframe of the nozzle. Here, further progress can be expected from the development of improved convergent-divergent nozzles with short length. In particular, for the reduction of base-drag by accurate nozzle integration for twin-engined airplanes the solutions presently available are still inadequate, and much more attention and work should be devoted to this highly important problem. Future requirements for improved high-angle-of-attack flight capabilities will eventually be met by thrust-vectoring nozzles.

4. ENERGETICS

4.1 Future Aviation Fuels

Turning to energetics, the most important and vital

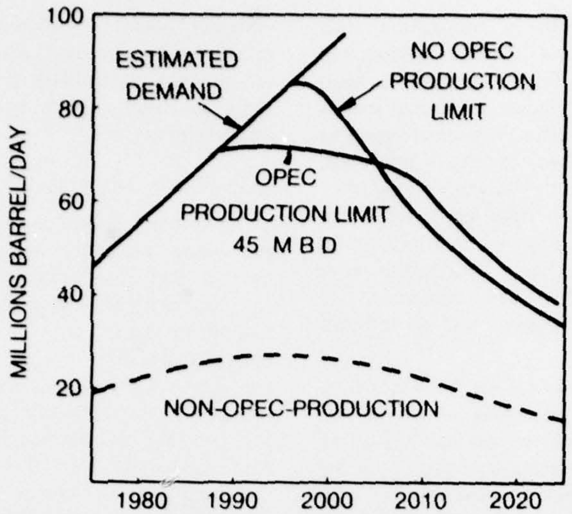


Fig.15 Expected petroleum shortages, assuming different models for crude oil production[11]

	NEW	JET A
MAX. BOILING POINT	606 K	567 K
MAX. FREEZE POINT	244 K	233 K
MAX. ALLOWABLE AROMATICS (VOL)	35%	20%
HYDROGEN CONTENT (WEIGHT)	12,8%	≃ 14%

Fig.16 Key properties of possible broad-specification fuels[13]

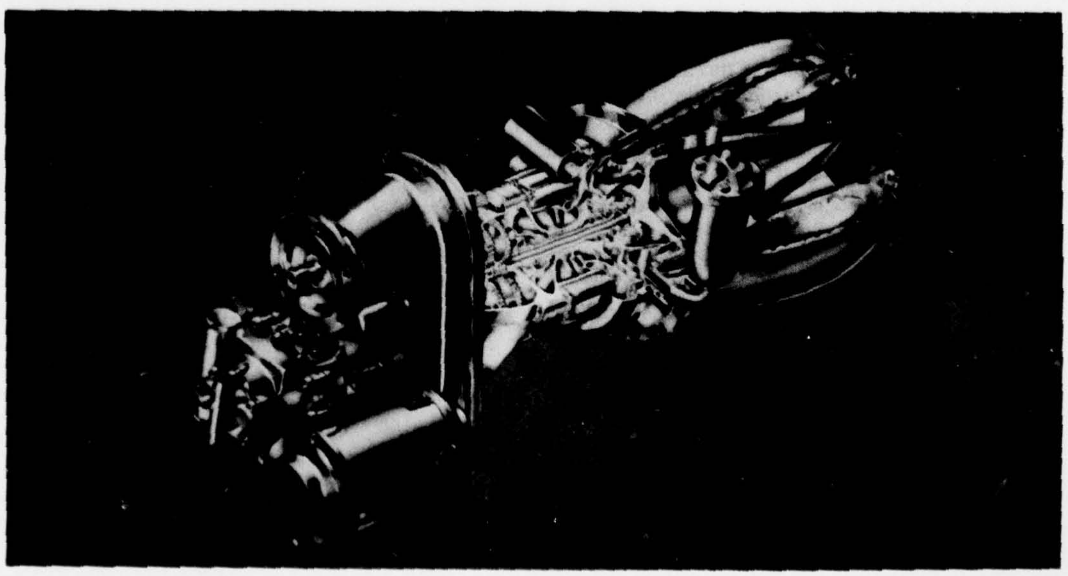


Fig.17 Advanced emergency power unit. (Courtesy Aero Prop. Lab., USAF)

problem which we have to address is the fuel problem. Middle distillate hydrocarbon fuels are nearly ideally suited for aviation purposes, due to their favourable properties (heat content, density, storability etc.). However, as is well known and illustrated by Figure 15, towards the end of this century we will be faced with a serious gap between the steadily rising demand for hydrocarbon products and the declining crude oil supply. As aviation consumes only a limited amount of the total sum of hydrocarbon products, between 6% now and approximately 9–10% in the Nineties, this gap means decreasing availability, increasing competition from other users, like Diesel engines, and hence increasing prices. It is therefore vital for aviation to secure an adequate fuel supply at reasonable prices; in particular for the airforces. Two ways will be followed.

The first way is to increase fuel availability by widening the presently rather narrow specifications to which an aviation fuel has to be produced. A proposal for this is shown in Figure 16. If excessive hydrogenation is to be avoided, the boiling range and the aromatic content has to be increased above present values (Jet A), giving rise to combustor problems, like increased liner temperatures, increased soot formation, increased pollutant production etc. The second way which has to be followed is the search for alternative fuels, made from oil shale, tar sand or from coal liquefaction products. Available results of research work in this direction show that these raw materials allow the production of adequate aviation fuels. However, many problems remain to be solved before the use of alternative fuels becomes common practice. Much work needs to be done on energy-efficient production of new hydrocarbon fuels, on methods of how to overcome the detrimental effects of combustion of these fuels in new aero engines, on their compatibility with existing equipment both aircraft and engines, which are likely to be in service until the end of the century or longer – on multi-fuel capability of combustors, which will be required for a certain time period, where fuels made to old and to new specifications will be in use at the same time. It is one of the PEP's future prime objectives to stimulate these activities on an alliance-wide basis, as will be done in particular by our new Working Group 013 on Alternative Jet Engines Fuels.

4.2 On-Board Power Generation

Modern military aircraft require auxiliary power in the order of 150 kW continuously and 250 kW for short periods. The trend towards more sophisticated electronics and weapon systems will eventually cause these figures to rise even more. This can seriously compromise engine performance, particularly under high-altitude conditions, if the auxiliary power is extracted from the engine shafts, as is the case at present. Therefore, it is desirable to have available an independent continuously-running power supply, the output of which does not degrade with increasing altitude. This demand is a considerable challenge for the development of suitable power systems based either on gas turbines or on other principles. Furthermore, the use of active control techniques in control-configured vehicles (CCV) needs an uninterrupted power supply, in particular in case of a failure of an engine or the auxiliary power system. This requires emergency power units, which can immedicately provide the necessary electric or hydraulic power. A suitable candidate is the small gas turbine which can be quickly started and run up with oxygen before being switched to air as oxidant.

Figure 17 shows such a system which is under study by the US-Air Force Aero Propulsion Laboratory. On the ground, it can be used as a normal APU, using air for the combustion of kerosene. Another alternative is the use, in an emergency gas turbine, of a self-decomposing monofuel, such as hydrazine-based fuel or nitrous oxide – N_2O, which decomposes to oxygen that can be burnt with kerosene, using the remaining nitrogen as dilutant. Other possibilities are offered by emergency batteries, which are capable of three to five minutes of operation after an electrolytic liquid is injected. These examples may show that there is ample space still left for new ideas in the development of advanced on-board power systems, which can meet future power demands. PEP will, in the future, have to pay attention to this field which is so vital for the safe operation of modern military aircraft.

MISSILE PROPULSION

Missile propulsion, including rocket motors, ram-rockets and ramjets, are of the greatest importance for the armed forces of the Alliance. Recent years' progress in the field of target acquisition, homing and guidance techniques have led to ambitious concepts for advanced missiles, the realisation of which, however, needs comparable progress in missile propulsion technology. Therefore, main goals of modern missile propulsion developments are

- the improvements of fuels with respect to performance, density and detectability of the exhaust gas trails,
- the increase of the flexibility of the propulsion systems by thrust control, thrust termination and re-ignition capability,
- the increase of fuel efficiency by the use of ram-jets and ram-rockets.

For solid rockets and ram-rockets fuels with metallic additives are now available which have high densities and high specific impulses in the order of 265–270 sec. However, a further increase of these figures will be rather limited. On the other hand, the detectability of exhaust trails of solid fuel rockets has been considerably decreased by combinations of the classical double-base and composite propellatns, as well as by the use of nitramines as oxidants. Here further progress can be expected in the future. Methods for thrust control have been found, permitting also termination and re-ignition of combustion, thus increasing the flexibility of solid rocket motors.

In the past, liquid-fuel rocket motors stood in the shadow of successful solid-rocket motor development; this is very regrettable, because due to its high potential for thrust control, and hence manoeuverability, they are very well suited, in particular, for surface-to-air-missiles. However, meanwhile much progress has been achieved with respect to their handling qualities and in its modern "prepacked" shape the liquid-fuel rocket motor can be handled as easily as a solid-rocket motor. Future progress will result from efforts towards improved thrust control and reduced costs.

For missiles with higher-range requirements air-breathing propulsion systems are gaining increasing importance. Whereas for subsonic and low supersonic

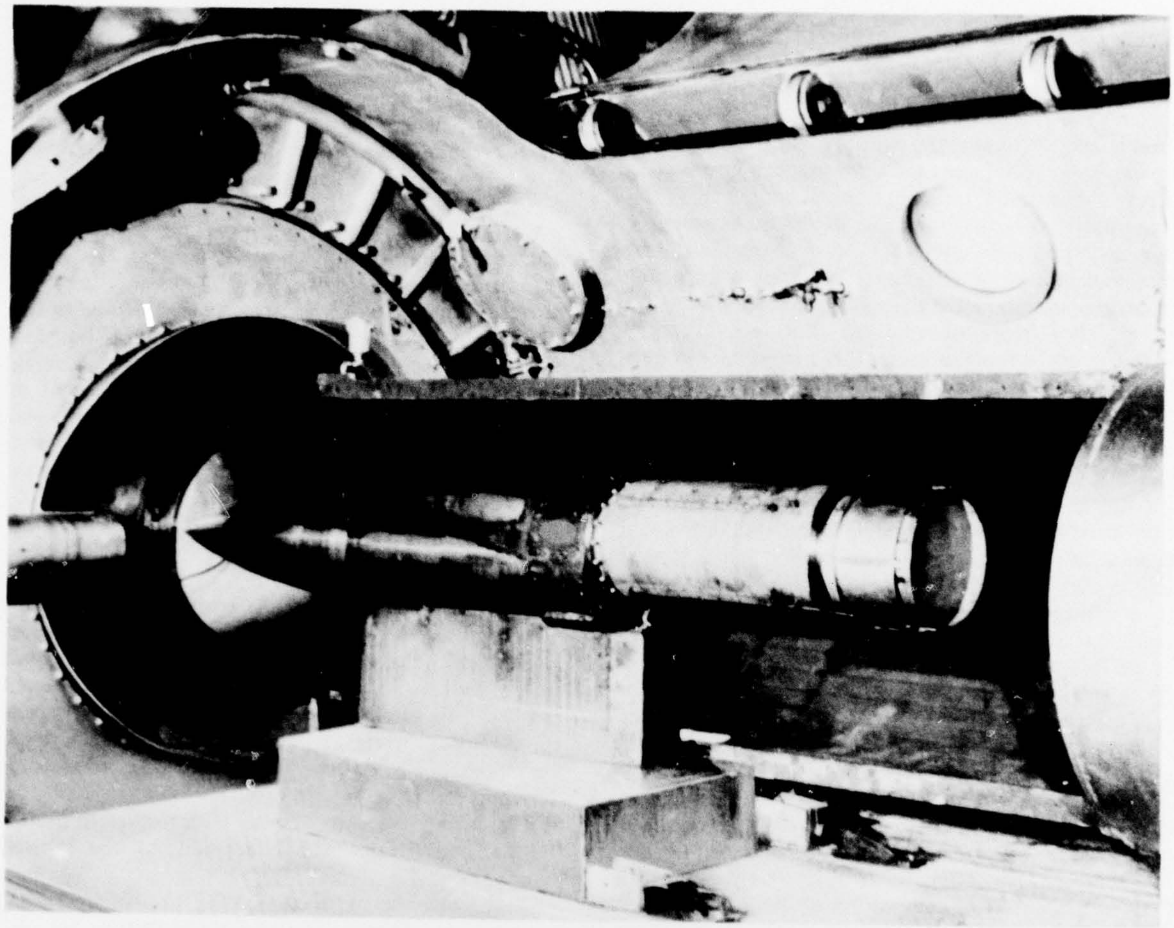


Fig.18 Ramjet engine for an Advanced Strategic Air-Launched Missile (ASALM) on an altitude test bed. (Courtesy Aero Prop. Lab. USAF)

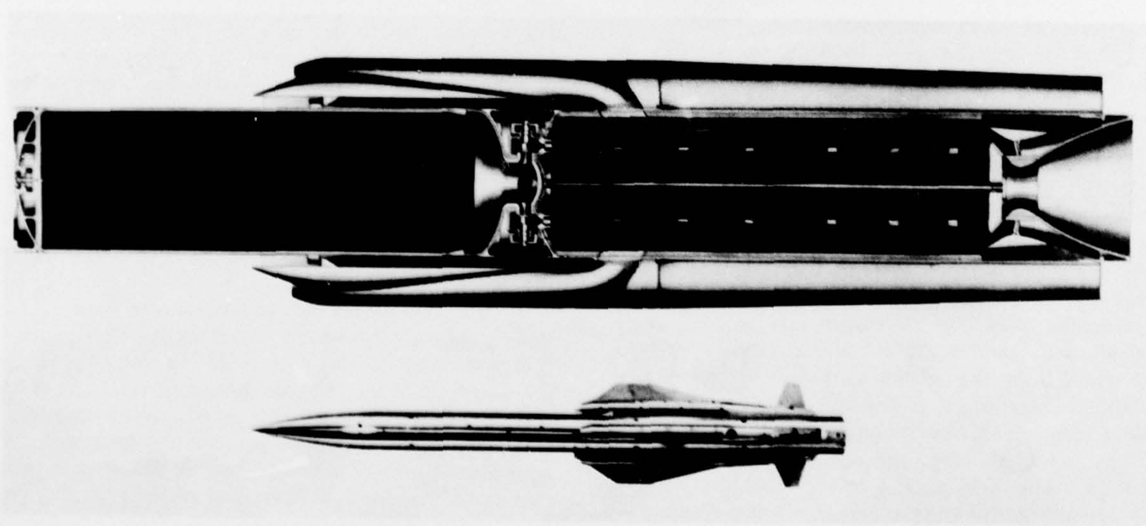


Fig.19 Solid-propellant-ramjet engine with integrated booster. (Courtesy MBB)

cruise missiles for long range low-cost limited-life turbojets and turbofans are best suited, ramjets and ram-rockets or ducted rockets are the prime candidates for supersonic flight velocities and medium range. Both liquid fuel and solid fuel ramjets are in use or under development for the air-breathing flight phase. An example for the latter type is the engine for a US Advanced Strategic Air-Launched Missile (ASALM), shown in Figure 18 on a high-altitude test-bed.

After the successful integration of the solid rocket booster into the ramjet combustor, further progress can be expected from high-density fuels, like liquid Shelldyne blends or solid propellants with boron or, in the future, lithium. Furthermore, improved thrust control will lead to higher manoeuverability of missiles, particularly in the end-phase of the flight. Figure 19 shows an example for such a type of modern ducted-rocket engine, using a high-density boron solid-propellent and permitting a three-to-one throttle ratio. It was recently selected for the use in Europe's future air-sea-missile ASSM.

CONCLUSIONS

In attempting to summarize the future prospects for propulsion, it is on the one hand safe to say that, despite their high technological level, modern propulsion systems still possess a great potential for performance improvements, the exploitation of which will be enforced by future mission requirements and the general energy situation. On the other hand, the increasing complexity of engines has led to considerable increases in costs for engine development and manufacturing; therefore, international co-operation of engine manufacturers in new engine projects is now a well-known practice. Since the price to be paid for future performance gains will certainly be higher than that of fifteen or twenty years ago, it will be all the more important to back the needed progress by carefully selected and well-guided research and development activities, in which exchange of experience and data will be beneficial for all sides. This is the field in which PEP will carry on with its activities, in enhancing discussions and exchanging experience, and in assessing the progress achieved on those current and adavanced topics which are of high interest for the Alliance as well as for progress in technical development. A careful selection of meeting and working group subjects together with advice in disputed or new problem areas will help to satisfy the needs of designers and users. The main areas of PEP's future work in the field of aero-turbine propulsion will thus be the achievement of higher specific power, better cost- and energy-efficiency, or the reduction of development risks by improved basic knowledge and advanced design and calculation techniques, new digital control techniques and their integration into the aircraft flight control system, or improved engine-airframe integration, as well as reduced detectability. In the field of missile propulsion – both air-breathing and rocket – PEP should enlarge its activities (as is already the case), emphasizing areas like improved flexibility of solid-fuel rockets and ramjets or high-performance fuels. The third aspect (energetics) will also receive proper attention, first in the fuel area, the importance of which cannot be over-emphasized, and second with respect to secondary-power-generation for aircraft. Let me conclude by re-calling that gas turbines are one of PEP's main working areas. These machines are presently expanding their fields of military application outside the aerospace field. They power many ships of the Alliance's navies, and there is a future prospect for their use in battle tanks, too. They furthermore are expanding their share in power-generation and other industrial applications. It seems logical to me that PEP should not forget the specific needs of these non-aerospace applications, in order to make best use of PEP's expertise for the benefits of the Alliance.

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SUMMARY OF 1979 MEETING THEMES

AEROSPACE MEDICAL PANEL

Specialists' Meeting: **Maintenance of Air Operations while under Attack with Chemical Agents** (Classified). **Recent Advances in Aeronautical and Space Medicine**
22–26 January 1979, Brussels, Belgium

At this meeting, the first session (classified), entitled 'Maintenance of Air Operations while under Attack with Chemical Agents', will deal with the chemical warfare threat to air operations, the effects of chemical warfare agents, their detection and prophylaxis, the philosophy of protection against chemical warfare agents, the methods of providing this personal and collective protection and the physiological and operational penalties imposed by the chemical defence measures currently available and under development for aircrew. For the second session (unclassified), the topic 'Recent Advances in Aeronautical and Space Medicine' has been retained from the previous year's programme to present the significant medical advances regarding the problems of the selection of aircrew and astronauts, and supersonic and very long duration flight.

36th Panel Business Meeting/Specialists' Meeting: **Aircrew Systems and Human Factors in Future High-Performance Aircraft. High-Speed/Low-Level Flight – Aircrew Factors**
22–26 October 1979, Lisbon, Portugal

The Fall meeting will cover in its first session the subject of 'Aircrew Systems and Human Factors in Future High-Performance Aircraft', dealing with the operational characteristics of high-performance aircraft with emphasis on the physiological and psychological effects imposed on the aircrew. For the second session, the subject has been chosen to review, modify, and improve current operating systems, define operational needs and resulting operational conditions, pathophysilogical and performance limits, discuss methods to enhance performance, and improve survival.

A Lecture Series will be sponsored by the Panel on the subject of 'Intensive Air Operations: Problems of Sleep, Wakefulness and Circadian Rhythms' (see under the later heading of Lecture Series for further details).

AVIONICS PANEL

37th Panel Meeting/Symposium: **Avionics Reliability, its Techniques and Related Disciplines**
9–13 April 1979, Ankara Turkey

The Spring Symposium is entitled 'Avionics Reliability, its Techniques and Related Disciplines'. It will seek management and engineering approaches to definition (specification) of meaningful reliability requirements and the methods of achieving them.

38th Panel Meeting: **Modelling and Simulation of Avionics and Command Control and Communications Systems.**
15–19 October 1979, Paris, France

The Fall Symposium will examine 'Modelling and Simulation of Avionics and Command, Control, and Communications Systems'. With advances in computers and component technology, simulation is being used increasingly in avionics systems. This Symposium will cover the methodology and economics of simulation, simulation languages, computer techniques, and simulation applications, to provide an understanding of each aspect of simulation to optimize its use in the context desired.

ELECTROMAGNETIC WAVE PROPAGATION PANEL

Symposium: **Special Topics in HF Propagation**
28 May – 1 June 1979, Lisbon, Portugal

The purpose of this Symposium will be to examine in depth the current knowledge of HF propagation in all its current and contemplated uses, and permit exchange of information concerning requirements, capabilities and future research effort.

26th Panel Meeting/Specialists' Meeting: **Terrain Profiles and Contours in EM Propagation**
10–14 September, Spåtind, Norway

This Specialists' Meeting will address propagation problems associated with profiles and contours of the terrain. Theoretical aspects of digital terrain mapping, criteria of terrain shielding, terrain effects on antenna characteristics, and subsurface contours and profiles will be examined.

FLUID DYNAMICS PANEL

44th Panel Meeting/Symposium: **Aerodynamic Characteristics of Controls**
14–18 May 1979, Naples, Italy

This Symposium will focus on improving our understanding of the factors that determine aerodynamic effectiveness of controls. The flight envelopes of aircraft are being continuously expanded and increasing use is being made of electronic technology to assist the pilot and indeed take over this traditional role. Much effort is now being applied to the development of active control technology involving the use of controls in closed-loop stabilising systems with consequent design, handling and performance improvements, and thought is being given to controls suitable for direct lift (including side-force) control.

The increasing demands made of controls call for more accurate methods of predicting control characteristics, including interference effects, and exploration of novel methods of control. These include not only the traditional aerodynamic control surfaces, but also spoilers, tailerons, wingerons, flaperons, elevons, canards, blown controls, leading edge controls, vectored thrust controls, etc.

The Symposium will aim to reveal the more important problems with which we are faced and to determine the lines along which research should prove most fruitful. Experimental data covering all flight conditions including transonic speeds and high angles of attack will be included. Also invited will be studies of dynamic characteristics in manoeuvres, quick acting controls, effects of interference gaps and buffeting, experiences gained in active control in direct lift systems, prediction methods, and related problems of controls for missiles.

45th Panel Meeting/Symposium: **Turbulent Boundary-Layers – Experiments, Theory and Modelling**
24–28 September 1979, The Hague, The Netherlands

Turbulence is the principal unknown in any rational design of aircraft. In spite of very significant advances in computing techniques, the modelling of turbulent shear flows still rests on quite insecure foundations. A better understanding of turbulent boundary layers is crucial for further advances in aircraft performance prediction. The flux of mass momentum, and energy in laminar flow are proportional to the local gradients of concentration, velocity, and temperature. There exists no similar simple rule relating flux terms in turbulent flow to the corresponding gradients. In recent years, theory and modelling on one side and experiments on the other have followed diverging directions in turbulent research. Recent experiments have demonstrated the persistence of coherent structures in turbulent shear flows and consequently have cast doubt on the usual local transport relations and even on the usefulness of Reynolds averaging, used in practically all modelling approaches.

It is the purpose of the symposium to take stock of the present situation in turbulence research and to attempt, by bringing together experimentalists and theoreticians, to map out new directions in modelling and experimentation. In order to concentrate on one of the most important applied problems, the symposium deals specifically with turbulent boundary layers, in both incompressible and compressible fluid flow. Invited papers will include experimental studies aimed at a clarification of physical phenomena in turbulent boundary layers, such as the persistence and interaction of turbulent spots, the existence and effects of longitudinal vortices near a solid boundary, and the mechanism of the bursting phenomenon. Also to be invited are reports of analytical and numerical work which

either attempts to incorporate the recent experimental findings into a turbulence model or addresses the proposition that the observed coherent structure need not be considered in models aimed at a prediction of averaged boundary-layer properties. Finally, although laminar-turbulent transition is outside the scope of the symposium, results on possible persistent after-effects of transition on the turbulent boundary layer will be solicited.

FLIGHT MECHANICS PANEL

54th Panel Meeting/Symposium: **Missile System Flight Mechanics**
21–25 May 1979, London, United Kingdom

Missiles, like manned aircraft, are required to achieve certain goals in performance and controlability, they also have to obey the same laws of dynamics and aerodynamics and, while speeds, rates, and dynamic characteristics may be very different, the flight mechanics of missiles and of manned aircraft are fundamentally the same. For many reasons, however, the application of the laws of flight mechanics to missile and manned aircraft design have been applied differently. There is, therefore, much to be gained from a cross-fertilisation of the expertise in the two technologies.

It is considered appropriate that the initial FMP activity in this field should be a restricted one, dealing with the flight mechanics aspects of air-launched missiles that rely, to some extent, on aerodynamic means of achieving the required control and performance capabilities. Emphasis will be given to short range tactical missiles and guided weapons of the air-to-air and air-surface types, with consideration of longer range air-surface missiles and of systems with a look-down shoot-down capability. The impact of requirements for launch compatibility with fixed and rotary wing aircraft will be examined. The Symposium will consist of five sessions, including a round-table discussion, and a workshop that will present the very latest results and findings. The first session will cover the complete missile, from an overview of evolution and design development, through current requirements, to a discussion of the implications on missile flight mechanics of recent developments in guidance and control systems technologies, that have been made possible by advances in solid state avionics and digital processors. The second session will deal with design/development, including such things as preliminary design techniques and methods for meeting manoeuvre requirements. Session three will cover simulation and flight testing including performance, manoeuvre and hit simulation, test instrumentation and techniques and range requirements. Operational aspects will be covered in session four, with emphasis on experience and its impact on future requirements; also the problems of the man in the control loop will be discussed. Finally, a round-table discussion will explore the benefits to be obtained from an interchange of manned aircraft and missile technologies and will assess the possibilities for improved cost effectiveness.

55th Panel Meeting/Symposium: **The Use of Computers as a Design Tool**
3–7 September 1979, Münich, Germany

The complexity of aircraft design procedures, the large financial investment and technical efforts involved, and the increasing importance of the basic initial options in any new aircraft programme require heavy reliance on computers to generate valid and competitive solutions. The rapid and great advances in computer hardware and software, and the more and more specialized nature of computation, have resulted in the generation of a new breed of computer system engineers. There has been a tendency for two diverging groups to emerge: one group highly specialized in computing and knowing little about design, the other very familiar with design, but with limited knowledge in computing. This undesirable situation could be avoided by improving the communication between the designer and the computer specialist. There is also a need to overcome the problems of communication between the designer and computer itself and to handle the difficulties arising from the need for perpetual updating of computer programmes.

With these points in mind it is intended that this Symposium will cover the topic under four session headings. The first of these will investigate the present and future potential of small and large computer systems including such items as data collection and optimization techniques and computerised drawing. The second session will be on the use of computers in aircraft specification; covering such areas as operational research and mission definition for military aircraft and market survey and fuel economy for commercial aircraft. The third session, on the computer as a preliminary design tool, will examine the impact of recent advances. These have not only led to the possibility of making more detailed studies, but also to a tendency for development of either a modular design process, with numerous iterations between various specialised teams, or an integrated process based on a large interdisciplinary programme; the advantages and disadvantages of these will be discussed. The final session will look at the use of computers in detailed design and development. The areas covered will be aerodynamic programmes, including such items as wing design and airframe/propulsion integration; structural analysis, including aeroelasticity/handling qualities interaction and flutter; and more general items such as flight testing and system integration and

development. Throughout all the sessions emphasis will be placed on the financial implications of using the systems described and, in particular, their limitations.

GUIDANCE AND CONTROL PANEL

28th Panel Meeting/Symposium: **Advances in Guidance and Control Systems using Digital Techniques** (Classified)
7–11 May 1979, Ottawa, Canada

The Spring Symposium (NATO-CONFIDENTIAL) will deal with applications of microprocessors to guidance and control, application of advanced analytic and design methods, software design, simulation and validation techniques, multi-sensor landing for increased performance and fault tolerance, redundancy management and operational and development performance with these advances.

29th Panel Meeting/Symposium: **Air Traffic Management: Civil/Military Systems and Technologies** (Classified)
8–12 October 1979, Copenhagen, Denmark

The Fall Symposium will focus on applications to tactical situations in the NATO environment, thus requiring classified sessions (NATO-SECRET). Based on the presentation of possible operational scenarios, the conference will discuss the adequacy of those air traffic control concepts in current use and critically review recent advances including: digital data links, computer architecture, global positioning, automatic distribution of information, displays, processors and integrated systems. The transition to a future civil/military system using the most advanced techniques will be considered, and evolutionary implementation schemes will be proposed.

PROPULSION AND ENERGETICS PANEL

53rd Panel Meeting/Symposium: **Solid Rocket Motor Technology**
2–6 April 1979, Oslo, Norway

The Symposium, on 'Solid Rocket Motor Technology', is aimed at furnishing a comprehensive survey of the technology available for solid propellant rocket motors and its further development capabilities. Both research and technology problems will be discussed. Separate sessions will be devoted to ignition and extinction problems, and internal ballistics, to the combustion of metals and particles (considering both the basic problem of single particles as well as the combustion of particle clouds), and to smokeless propellants. Particular attention will be given to combustion instability, its analysis, and relation with dynamic properties of propellants and comparison between theoretical predictions and observations. High frequency instabilities, velocity coupling, suppression devices and the dynamic performance of nozzles are important features and will be discussed. The Symposium will be concluded by sessions concerned with heat transfer in nozzles and nozzle liners including suitable insulation materials as well as with testing and instrumentation which both will be covered in the aspect of laboratory work, development, and flight.

54th Panel Meeting/Specialists' Meetings: **Advanced Control Systems for Aircraft Powerplants.**
1–5 October 1979, Cologne, Germany **Combustor Modelling**

The first Specialists' Meeting relates to the fact that in recent years considerable progress has been achieved in digital electronic techniques and their use in control systems. This Meeting will review the state-of-the-art and discuss the optimum control strategies for aero engines, the possibilities of integrated engine intake and flight control systems with respect to future military aircraft. The implementation of control by advanced hydro-mechanical, fluidic, or electronic systems will be included and redundancy strategies and system integrity analyzed and compared with recent experimental experience of advanced engine controls.

The second Specialists' Meeting will deal with 'Combustor Modelling'. This Meeting addresses research workers of aero-engine manufacturers and other related industries as well as of institutes. Its objectives are to help manufacturers in selecting and substantiating adequate theoretical models and, on the other hand, to provide university researchers with knowledge about realistic combustors and on the experimental conditions under which theoretical models should be validated. Discussions will be focussed on purely theoretical work and its comparison with

experimental data. One part of the meeting will deal with elementary phenomena like fuel injection and vaporisation, overall models of chemical kinetics, aerodynamics of primary and dilution zones, modelling of gas and metal radiation, and will include non-stationary phenomena, e.g., ignition and instabilities. In a second part, synthesis of elements and application of models to performance, operation and optimization of main combustors in turbine engines, after-burners, and industrial combustors will be discussed as well as the pollution prediction capabilities, e.g., the generation of carbon monoxide, nitrogen oxides, unburned hydrocarbons and smoke.

For the Specialists' Meeting on 'Ceramics for Turbine Engine Applications', which will be sponsored by the Structures and Materials Panel, PEP will take the responsibility for the session on 'Systems Design Analysis' and share sponsorship with SMP for the session 'Ceramic Component Design and Test Experience', as well as for the round-table discussion.

STRUCTURES AND MATERIALS PANEL

48th Panel Meeting/Specialists' Meetings: **Damping Effects in Aerospace Structures. Low-Cost Aircraft Flutter Clearance**
1–6 April 1979, Williamsburg, USA

The Spring Panel Meeting will include two Specialists' Meetings, as follows. The main Meeting will be on 'Damping Effects in Aerospace Structures' which will deal with the type of aerospace problem where damping is of crucial importance and for which no systematic treatment has yet been attempted from a practical point of view. The second will be a one-day Meeting on 'Low-Cost Aircraft Flutter Clearance' which will review low-cost flutter prediction procedures, especially with regard to light airplanes and gliders.

49th Panel Meeting/Specialists' Meeting: **Ceramics for Turbine Engine Applications**
8–12 October 1979, Cologne, Germany

It is becoming increasingly apparent that uncooled ceramic components may be one of the best ways of meeting anticipated system requirements for engines with higher thrust-to-weight and thrust-per-unit-volume ratios for missile and RPV applications. Many of the programmes currently under way are addressing and solving the design problems outlined in a previous AGARDograph and a number of important lessons has already been learned about the selection and processing of ceramic materials for these applications. Sharing this information now and updating earlier publications in this area should greatly accelerate the development of ceramic engine technology. The Propulsion and Energetics Panel is participating in the preparation of the programme for this Meeting.

TECHNICAL INFORMATION PANEL

32nd Panel Meeting/Specialists' Meeting: **International Access to Aerospace Information**
16–18 October 1979, Athens, Greece

One of the main elements of the work of the Technical Information Panel is to assist NATO's aerospace research and development activities by improving the effectiveness of scientific and technical information systems throughout the member nations. The choice of theme for the 1979 Specialists' Meeting stems from consideration of this aspect of TIP's work. The Meeting will provide a survey of the existing facilities for international access to aerospace information and the problems involved. Thus, examples of official aerospace information channels will be reviewed. Technical requirements and apparent barriers to international cooperation and data exchange will also be addressed. Furthermore, the Meeting will take notice of special problems associated with aerospace information, such as access restrictions to certain types of document and full-text information, and the utilization of numeric aerospace data. It is planned to terminate the meeting with a half-day Workshop Session to address problems raised by members of the host nation in relation to aerospace information in the conduct of Greek research and development work.

LECTURE SERIES

Lecture Series No.98: **Missile Aerodynamics** (with Fluid Dynamics Panel)
5–6 March 1979, Ankara, Turkey
8–9 March 1979, Rome, Italy
12–16 March 1979, Brussels, Belgium

The course will cover all the chief aspects of the aerodynamics of tactical missiles. It will be introduced with an extended overview of the more classical topics, such as flow over wings and bodies, wing-body and wing-tail interference and aerodynamics of complete configurations. This course will be a follow-on from the previous VKI Lecture Series organized in 1976, in that the following more specialized topics related to improved design of missiles will be treated in more detail:

- control of missiles, high angle-of-attack aerodynamics, base flow, and
- weapon-aircraft interaction (stores and stores separation).

At the von Kármán Institute presentation of the Lecture Series, VKI will sponsor an additional 2½ days of lectures to cover the areas of kinetic heating, internal flows in airbreathing engines and external aerodynamic aspects of intakes. The published Proceedings will contain an extensive documentation of the subject (additional to all the oral presentations) and as such will be a valuable reference document.

Lecture Series Director: Dr B.E.Richards, Von Kármán Institute, Brussels, Belgium.

Lecture Series No.99: **Aerospace Propagation Media Modelling and Prediction Schemes for Modern Communications, Navigation, and Surveillance Systems** (with Electromagnetic Wave Propagation Panel)
4–5 June 1979, London, UK
14–15 June 1979, Boulder, USA

This Lecture Series will review modelling and prediction topics which have been presented at a number of meetings of the AGARD Electromagnetic Wave propagation panel in the last few years. Modelling and prediction schemes of the aerospace radio and optical propagation environment based on media characterization have become essential to meet requirements of operational accuracies in communication, navigation, and surveillance in military and civilian systems.

The lectures will include the following topics:

General modelling and prediction schemes.
Aerospace (atmosphere ionosphere, and the space environment).
Short- and long-term prediction techniques and agreement with observation data.
Adaptability of prediction techniques to radio and optical communication, navigation and surveillance.
Systems operating in the aerospace environment.
Effects of geophysical disturbances on the state of the media and their predictability.

Lecture Series Director: Dr H.Soicher, US Army Communications Research and Development Command, DRDCO-COM-RF-5, Fort Monmouth, New Jersey, USA.

Lecture Series No.100: **Methodology for Control of Life-Cycle Costs for Avionics Systems** (with Avionics Panel)
7–8 May 1979, Bonn, Germany
10–11 May 1979, Athens, Greece

The continually increasing costs of avionics systems during acquisition and their lifetime operation is a matter of grave concern to the NATO family of nations. The NATO Governments need greater visibility and control over the life-cycle costs of all weapon and avionic systems.

Fortunately, there have been formulated disciplined methods of providing such visibility and control over life-cycle costs; that is, over the development, acquisition, training, operating and support and, finally, disposal costs.

This Lecture Series presents the basic principles of Avionics Systems Cost Analysis in a rapidly changing technology environment and gives proven methods of achieving significant cost savings.

The Lecture Series will cover the following subjects:

Life-cycle costing (LCC)
Cost estimating methods,
Procurement techniques,
Source selection methods.

Design to Cost (DTC)
DTC is a management concept with unit cost objectives.

Technology Environment
Technology changes affect the cost and effectiveness of avionics systems.

Costing of Software
Discussion of costs and methods for reducing them.

Modelling
Mission Completion Success Probability Model (MCSP) and Design System Performance Cost (DSPC) model and other models incorporating reliability factors would be discussed.

Applications
This final session deals with the applications of the principles of LCC and DTC and the cost savings achieved.

Lecture Series Director: Dr I.G.Gabelman, Technical Associates Rome (NY), USA.

Lecture Series No.101: **Guidance and Control for Tactical Guided Weapons with Emphasis on Simulation and Testing** (with Guidance and Control Panel)
4–5 June 1979, Rome, Italy
7–8 June 1979, Ankara, Turkey
11–12 June 1979, Eglin AFB, USA

With the advent of modern control theory, a strong research effort has to be undertaken to investigate its impact on tactical guided weapons. To effectively accomplish this objective, it will be extremely beneficial to summarize the state-of-the-art of guidance and control for tactical weapons.

The tentative outline is as follows:

Introduction
Weapon delivery (target, acquisition and weapon delivery aspects).
Missile dynamics and control techniques (modern control application, higher order guidance, bank-to-turn control).
Missile guidance techniques (midcourse and terminal, guidance sensors, processing).
Guided weapon simulation techniques (digital, hardware-in-the-loop: development, validation).
Testing of missile guidance and control systems (new range techniques, interface with simulation).
Summary – Future trends.

Lecture Series Director: Mr C.T.Maney, Director, Plans and Research, USAF Armament Laboratory, Eglin Air Force Base, Florida 32542, USA.

Lecture Series No.102: **Bonded Joints and Preparation for Bonding** (with Structures and Materials Panel)
2–3 April 1979, Oslo, Norway
5–6 April 1979, The Hague, The Netherlands
15–16 October 1979, Dayton, USA

After more than 30 years of application in aircraft construction in roles with various degrees of structural importance, adhesive bonded joints are expected to see an increased use in more primary structural applications, both in conjunctions with metals as well as with advanced composites.

Basis for such advanced applications of bonded joints, however, must be ample knowledge of:

– structural design aspects,
– durability aspects

of bonded joints in order to provide the required static and dynamic strength of the bonded structure during its operational lifetime. With these demands in mind lectures are planned under the following headings:

Operational experience with adhesive bonded joints in military and civil aircraft.
The adhesive bonded joints as a fastening element in structures.
Fracture mechanical aspects of adhesive bonded joints and structures.
Materials and processes for adhesive bonded joints with optimum durability.
Special quality assurance aspects of adhesive bonded processes.
Non-destructive end-product inspection methods.

Lecture Series Director: Mr R.J.Schliekelmann, Fokker – WFWBV, Technological Centre, Schiphol, The Netherlands.

Lecture Series No.103: **Non-Destructive Inspection Methods for Propulsion Systems and Components** (with Propulsion and Energetics Panel)
23–24 April 1979, London, United Kingdom
26–27 April 1979, Milan, Italy

The safety of use of mechanical systems is dependent on the identification of possible defects in their components. This applies particularly to turbine engines, certain elements of which – in particular, turbine and compressor discs and blades – are subjected to extremely severe stresses: creep, low cycle fatigue, thermal fatigue.

These possible defects must be detected when the various parts are at the manufacturing stage, on the one hand, and, on the other, during periodic inspections when the engine is in service.

It is therefore indispensable to have available non-destructive inspection methods which, while they are accurate and sensitive, can be used in workshops for the detection of defects or cracks, however small they may be.

A considerable amount of research work has been conducted in this field on the world scale and has led to the development of various methods: ultra-sonics, magnetic inspection, X-ray pictures. New procedures, which are complementary to these already conventional methods, are in the process of development or optimization: acoustical emission, laser holography, Eddy currents, etc...

The aim of this Lecture Series is to survey the means currently available, with particular emphasis on the intrinsic possibilities and present limits of use of the non-destructive inspection methods the most widely applied to turbine engines, and to define the state-of-the-art of the most advanced methods.

Lecture Series Director: Ingénieur en Chef G.Bessonnat, Direction des Recherches, Etudes et Techniques, Paris, France.

Lecture Series No.104: **Parameter Identification** (with Flight Mechanics Panel)
29–30 October 1979, Delft, The Netherlands
1–2 November 1979, London, United Kingdom

The technique of Parameter Identification has been under development in a number of countries in recent years and, specifically, its application to the problems of analysis of flight test data has been examined by all the major NATO nations. As the last AGARD/FMP meeting on this subject was held in 1974, it was considered appropriate to bring together a number of experts in this field with a view to updating the information available and, in doing so, present it in the form of applications data and user experience so that it would be of practical value to the flight test engineer.

The lectures would examine basic theory and a number of applications of that theory to various areas of flight test work. The subjects covered include such topics as coefficient estimation including stability and control derivatives, performance and high angle-of-attack parameters, structural mode identification and turbulence, types of manoeuvre required; the purpose of parameters including vehicle compliance with specifications, definition of characteristics for simulation or refinement of configuration, and research to aid future design.

Lecture Series Director: Dr-Ing. P.Hamel, DFVLR, Braunschweig, Germany.

Lecture Series No.105: **Intensive Air Operations – Problems of Sleep, Wakefulness and Circadian Rhythm** (with Aerospace Medical Panel)
1–2 October 1979, London, United Kingdom
4–5 October 1979, Paris, France
9–10 October 1979, Toronto, Canada

The Lecture Series is intended for those concerned with the management of civil, and particularly military, personnel who have to cope with irregular work and rest. It will provide an understanding of the physiological processes involved in the adaptation of man to disturbed sleep and wakefulness, and consider approaches to the problem of management including the use of drugs.

The lectures will be given in three parts:

1. Sleep, Wakefulness and Circadian Rhythms. Physiological and Psychological.
2. Adaptation of Man to Disturbed Sleep and Circadian Rhythmicity.
3. Management of Irregular Rest and Activity.

In this first part, attention will be given to the physiological basis of sleep, wakefulness and circadian rhythms and the psychological correlates including performance relevant to personnel involved in skilled activity. The second part will review studies on the adaptation of man to unusual patterns of rest and activity with special reference to present day situations, and the third part will attempt to provide a basis for the management of disturbed rest and the rationality for the use of drugs.

The series is designed for a wide range of interests in both the civil and, particularly, the military context, and for the land, sea and air environments. A particular feature will be the opportunity for participants with special interest in the management of such problems to take part in discussions with the lecturers. It is intended that the participants will include managers and operation staff as well as medical officers.

Lecture Series Director: Wing Commander A.N.Nicholson, RAF Institute of Aviation Medicine, Farnborough, Hants GU14 6SZ, UK.

MILITARY COMMITTEE STUDIES

16th Meeting of the **Aerospace Applications Studies Committee** (Classified)
14–15 May, Washington, United States

The Committee will finalize the Terms of Reference for the topics selected by the National Delegates Board as ASS Nos. 12 and 13. They will also organize the Working Group No.12 which is going to start a new ASS in July 1979 if so decided by the National Delegates at their Spring Meeting.

4th Meeting of the **P-2000 Review Board** (Classified)
16–18 May, Washington, United States

The Review Board will receive the final briefings from the three Study Groups on their respective studies.

SG 1: Attack of Surface Targets
SG 2: Defence Against Missiles
SG 3: Detection, Location and Recognition of Ground Targets

and give ultimate guidance.

5th Meeting of the **P-2000 Review Board** (Classified)
19–21 November 1979, Munich, Germany

The Review Board will conduct the final review of the three Study Reports and the overall Executive Report from the Studies Coordinator.

This should be the last meeting of the Review Board.

17th Meeting of the **Aerospace Applications Studies Committee** (Classified)
22–23 November 1979, Munich, Germany

The Committee will conduct the initial review of Study No.12 if previously started, draft Terms of Reference of Study topics proposed by the Military Committee and organize Working Group for Study No.13.

Obituary

MICHAEL ANASTASSIADES

It is with deep regret that we record the death of Professor Michael Anastassiades, after a heart attack, on 28 October 1978.

Born in 1909, Michael Anastassiades graduated from the University of Athens and obtained a doctor's degree from the same university. Following additional studies at the Institute Electrotechnique at Grenoble and at the Ecole Supérieure d'Electricité de Paris, in 1937 he became a lecturer in applied physics at the University of Athens, with subsequent appointments as assistant professor, associate professor, and director of the ionospheric institute of the National Observatory of Athens. In 1960 he was appointed a full professor at the University of Athens and director of the physical electronics laboratory.

Since 1957, Prof. Anastassiades had been associated with AGARD, first as one of the founder members and later (1964/65) as chairman of the committee which is now the Electromagnetic Wave Propagation Panel (EPP). From 1960 to 1967 he was a National Delegate of Greece. In 1975, he again joined the EPP. Among other activities within NATO, he had represented Greece in the Science Committee and had been Director of Advanced Study Institutes.

Prof. Anastassiades will be remembered for his radiant personality and as a scientist of high international reputation well proven by his numerous scientific publications, among them several contributions to AGARD. His main fields of activity were electromagnetic wave propagation and ionospheric physics, space physics and radio meteorology. He was Vice-President of the Hellenic committee of the URSI (International Union of Radio Science) and President of the Hellenic Physical Society.

With the death of Michael Anastassiades AGARD has lost a friend and supporter; in mourning his passing we offer his family our heartfelt sympathy.

All members of AGARD, whether National Delegates, Panel Members or AGARD Staff, are cordially invited to submit articles likely to be of interest to other AGARD members for the next issue of AGARD HIGHLIGHTS which will appear in the Autumn of 1979. Articles should be addressed to:

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